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Analyzing the effectiveness of logistics networks during the immediate response phase of three different natural disasters

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MBA PROFESSIONAL REPORT

Analyzing the Effectiveness of Logistics Networks During the Immediate Response Phase of Three Different Natural Disasters

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By: **Ilyas Emre Gursoy, Mohamed Tahar Brahim, and Osman Onder**

December 2010

Advisors: **Dr. Susan K. Heath, Bryan Hudgens**

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Every year, natural disasters affect millions of people around the world. Natural disasters are an unavoidable part of our lives but effective disaster management increases the number of survivors and helps the victims. After disaster hits, the most important job is enabling an effective response operation. This operation involves many logistics activities and some special demand for relief goods. Today, supply chain management increases the effectiveness of logistics activities for many companies. The same thinking and modeling may help increase the effectiveness of response operations. An important milestone for this achievement is to be able to evaluate the performance of response operations in system thinking. In this project, we introduced three theoretical performance metrics: demand and supply equilibrium, transportation utilization, and information sharing, which help analyze the performance of overall response operations. We chose three different types of natural disasters: Hurricane Katrina, the 2004 Asian Tsunami, and the 2010 Haiti Earthquake to show the usefulness and applicability of these metrics. Unavailability of data associated with logistics operations made a thorough analysis impossible, but we assessed each disaster according to our metrics. The last part of this project focuses on the managerial implications of response operations considering these three metrics.

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ANALYZING THE EFFECTIVENESS OF LOGISTICS NETWORKS DURING THE IMMEDIATE RESPONSE PHASE OF THREE DIFFERENT NATURAL DISASTERS

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ABSTRACT

Every year, natural disasters affect millions of people around the world. Natural disasters are an unavoidable part of our lives, but effective disaster management increases the number of survivors and helps the victims. After disaster hits, the most important job is enabling an effective response operation. This operation involves many logistics activities and some special demand for relief goods. Today, supply chain management increases the effectiveness of logistics activities for many companies. The same thinking and modeling may help increase the effectiveness of response operations. An important milestone for this achievement is to be able to evaluate the performance of response operations in system thinking. In this project, we introduced three theoretical performance metrics: demand and supply equilibrium, transportation utilization, and information sharing, which help analyze the performance of overall response operations. We chose three different types of natural disasters: Hurricane Katrina, the 2004 Asian Tsunami, and the 2010 Haiti Earthquake to show the usefulness and applicability of these metrics. Unavailability of data associated with logistics operations made a thorough analysis impossible, but we assessed each disaster according to our metrics. The last part of this project focuses on the managerial implications of response operations considering these three metrics.

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LIST OF ACRONYMS AND ABBREVIATIONS

DoD	Department of Defense
FEMA	Federal Emergency and Management Agency
GAO	Government Accountability Office
GPS	Global Positioning System
IFRC	International Federation of Red Cross and Red Crescent Societies
MRE	Meal Ready to Eat
NGO	Non-governmental Organizations
NRP	National Response Plan
RFID	Radio Frequency Identification
SAR	Search and Rescue
USACE	United States Army Corps of Engineers
WFP	World Food Program
WHO	World Health Organizations

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Sincerely, I. Emre Gursoy and Osman Onder

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Sincerely, Osman Onder

For my parents who brought me to this world,

For my dear wife Hela,

For my country and our Armed Forces in recognition of their great contribution in developing my personal, professional and academic skills.

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Sincerely, Mohamed Tahar Brahim.

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I. INTRODUCTION

A. BACKGROUND

The natural disasters that occurred during the last decade affected the global demographic, social, and economic environment in a way that had not happened before. The size of many disasters, like the Asian Tsunami in 2005, grew from regional to international proportions. The casualty toll was unimaginable in many of these catastrophes and, in the case of the Haitian earthquake in 2010, was estimated by experts to be more than 200,000 deaths and many hundreds of thousands injured and homeless. The demographic, social, and economic impact varied from domestic to international in scope as well. The effects were devastating, especially in the poor countries where the extremely weak infrastructure and the limited resources amplified the damage and the disasters' effects.

Through these disasters, many parties, including governments, international organizations and nongovernmental organizations developed much more awareness about the importance of relief operations and their role in limiting casualties and disaster impact. Humanitarian planning and assistance became a large-scale process involving many actors, employing complicated concepts and engaging tremendous resources. The simultaneous development of various information and communication technologies was also an important factor for humanitarians, not only in conducting operations but also in collecting and storing information for further analysis, feedback and knowledge management.

The failure in conducting efficient responses in many previous disasters led the humanitarian experts to consider preparedness as the ultimate key for successful responses and to consider logistics as its paramount function. "A significant stumbling block to better preparedness in the humanitarian sector has been the failure to have logistics recognized as an essential element of any relief operation" (Tomasini & Wassenhove, 2009). For the International Federation of Red Cross and Red Crescent Societies, preparedness is built around five blocks: human resources, knowledge

management, logistics, financial resources and community; “logistics earns respect as a central function” (Tomasini & Wassenhove, 2009). The role of logistics in relief operations has increasingly evolved to become a core competency for organizations like the United Nation Joint Logistics Command, the International Federation of Red Cross and Red Crescent Societies, and the World Food Program.

Meanwhile, the conceptual evolution of the commercial logistics and supply chain fields, as independent disciplines, created better opportunities for applying revolutionary concepts in supporting relief operations and opened room for their improvement. Although different in their goals, a new area of cross learning between the newly born field of humanitarian logistics and the existing field of commercial logistics was established. Improving the logistics operations and supply chain in both sectors has been, and continues to be, an active field of research. On one hand, commercial logistics developed many approaches to supply chain management such as the integrated supply chain approach, collaborative approach, balanced oriented approach, integral logistics approach, and adaptive and scalable approach (Hiber, 2002). On the other hand, challenges remain in the logistics humanitarian field when it comes to evaluating logistics operations in disaster relief. This is due to many factors, from the availability of accurate records and data from previous relief operations, to the chaotic effects on the environment of a disaster, as well as the characteristics of the humanitarian supply chain.

> Supply chain management performance is the result of a coherent end-to-end business model, an organizational design consistent with that business model and flawless execution of the different types of flows. This is what we refer to management quality that is the capability of a team to manage the system accordingly. Achieving this level of coherence can be difficult in the humanitarian context. (Tomasini & Wassenhove, 2009)

As a consequence, evaluating the logistics activities’ performances and establishing useful feedback is still an under-studied field. The absence of valuable metrics continues to complicate this necessary task.

B. PURPOSE

The objective of this study is twofold; the first is to establish an evaluative framework for the performance of logistics activities supporting the response phase of relief operations in natural disasters. The second is to apply this framework to three recent natural disasters: the Asian tsunami of 2005, Hurricane Katrina in 2005 and the Haitian earthquake in 2010. Applying this framework will simultaneously provide operational feedback and judge the relevance of the adopted metrics.

C. RESEARCH QUESTION

To conduct this study we have to answer the following research questions:

- How can we define the response time scope?
- What are the logistics activities during the response phase?
- What are the logistics requirements during the response phase?
- What are the concepts that we can apply from commercial supply chains?
- What are good evaluation metrics for the effectiveness of logistics networks?
- How can the supply versus the demand be analyzed during the response phase?
- What is the role of transportation in supporting the relief activities?
- What is the impact of connectivity and coordination?

D. SCOPE

This study focuses on the logistics activities during the timeframe of the response phase of natural disaster relief operations. Focusing only on the response phase timeframe is justified by the following reasons: At first, the importance of the response phase is that it is a short timeframe in which it is possible to save the maximum number of people in the affected population. The complexity, variability and uncertainty of the demand will also make it impossible to encompass all the different phases of disaster operations. Finally, this study is taking in consideration the limited availability of data and recorded information.

E. METHODOLOGY

The methodology of this research is as follows: It starts with a literature review of the basic concepts in the fields of disaster relief operations, commercial supply chains, and humanitarian logistics. A comparative framework based on evaluation metrics is then established. We apply this framework to analyze three cases and then present managerial implications and the results of this study.

F. ORGANIZATION OF THE STUDY

The study is organized in the following pattern:

Chapter I is an introduction for the topic "Analyzing the Effectiveness of Logistics Networks During the Immediate Response Phase of Three Different Natural Disasters." It provides an overview of the project, its purpose, the research questions, its scope, the applied methodology and its organization.

In Chapter II, we start with the basic definitions and concepts encompassing disasters' time periods, commercial supply chain and humanitarian logistics. The goal of this review is to provide an understanding for the three bases on which this work is built: disaster management, concepts of commercial supply chains and characteristics of humanitarian supply chains.

The third chapter will focus on establishing an evaluative methodology that will be applied to the disasters in question. To achieve this goal, we describe the set of activities undertaken during the immediate response phase and the factors affecting the logistics network during disaster relief operations. We define our performance metrics, mainly inspired from the commercial sector: the demand versus supply, the interrelationship between transportation and the logistics network and the level of information sharing. The use of these three metrics is justified by the fact that they are the most essential pillars when it comes to elaborating plans for a pro-active response.

In the fourth chapter, we apply this framework to the three mentioned natural disasters to assess and evaluate the logistics activities during their respective response

phases. The choice of these cases was driven by the availability of information and data, the large size of the disasters and the large resources employed for the response.

The fifth chapter formulates the managerial implications and recommendations, draws conclusions about the relevance of the employed metrics in evaluating the logistics performance, and exposes the lessons learned from the analysis according to these metrics.

The final chapter contains the global conclusion of this study and relates the possible perspectives and opportunities for developing similar and more advanced research.

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II. DEFINITIONS AND GENERAL CONCEPTS

In this chapter, we explore three different areas that pave the way for the performance metrics that help evaluate the response phase logistics operations in the next chapter. These areas include disaster time periods, commercial supply chain management, and humanitarian logistics. First, we look at disaster management to understand the general operations in different time periods. Secondly, we explore the commercial supply chain management to understand the components of the commercial supply chain. Finally we discuss humanitarian logistics to understand different goals between humanitarian and commercial logistics.

Commercial operations mainly focus on profit but disaster relief operations' main focus is humanitarian. So, we define the humanitarian aspects as well as the logistics and supply chain aspects in disaster response operations, which are also a kind of humanitarian logistics. We then try to harmonize commercial supply chain management with humanitarian goals.

A. DISASTER TIME PERIODS

Natural disasters of tremendous magnitude and impact have hit many areas all around the world in the beginning of the 21st century. As a result, disaster management gained more importance than in previous centuries. One of the easiest ways to understand the characteristics of disaster management is to analyze the disaster timeline. Since the origins of disaster research, researchers have devised and used various classification approaches related to the phases of disasters. The delineation of disaster periods provides a useful heuristic device for disaster researchers and disaster managers. These various approaches to disaster phases give researchers an important means to develop research, organize dates, and generate research findings (Neal, 1997).

Developing disaster phase models has been useful, particularly for understanding response efforts to emergencies and disasters (Richardson, 2005). Academicians have suggested many approaches to defining disaster timelines.. The National Governor's

Association separated the disaster timeline into mitigation, preparedness, response, and recovery that have been the standard terms used to describe the cycle of work related to emergencies and disasters (Edwards, 2009). Kovács and Spens (2007) defined the disaster timeline as the phases of preparedness, during operations, and post operations. Different operations can be divided into the times before a disaster strikes (the preparation phase), instantly after a disaster (the immediate response phase) and in the aftermath of a natural disaster (the reconstruction phase). Indeed, phase models have been developed in order to assign order and rationality to the very messy, complex reality of natural and technological disasters, and human responses to them (Richardson, 2005).

Although some researchers and academicians separate disasters into four phases, and some of the others separate it into five or three phases, and each give various names for the steps, in our project we define the phases as the pre-disaster phase, the response phase, and the recovery and reconstruction phase. Figure 1 illustrates these phases of the natural disaster management life cycle and the main activities during these three phases. This is a continuous cycle, in which each phase follows its predecessor consistently.

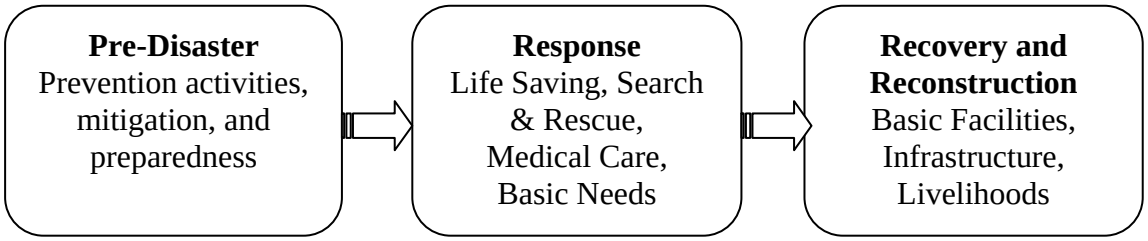

Figure 1. The Phases of Disaster Management Life Cycle

Often, the phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster. The activities during one phase (e.g., preparedness and/or mitigation) may influence how well (or poorly) responders, managers, or victims handle another phase (e.g., response or recovery) (Neal, 1997).

We will give a brief definition of the three phases, and then focus on the immediate response phase, which we believe affects all the post-disaster activities.

1. Predisaster Phase

The pre-disaster phase includes prevention activities, mitigation, and preparedness. Mitigation activities actually eliminate or reduce the probability of disaster occurrence, or reduce the effects of unavoidable disasters. Mitigation measures include building codes, vulnerability analysis updates, zoning and land use management, building use regulations and safety codes, preventive health care, and public education (Srinivas, 2010).

Preparedness involves activities and measures taken in advance to ensure effective responses to the impact of hazards, including the issuance of timely and effective early warning and the temporary evacuation of people and property from threatened locations (Goyet, 2008). Pre-disaster preparedness also typically includes a hazard and vulnerability analysis as well as the establishment of the response network, incident command plans, other planning, and a variety of training activities (M. Ginter, 2006).

2. Response Phase

The response phase consists of actions taken just prior to, during, and after disaster impact to reduce casualties, damage, and disruption and to respond to the immediate needs of disaster victims. These measures include detecting threats, disseminating warnings, evacuating threatened populations, searching for and rescuing trapped disaster victims, providing emergency medical care, taking action to contain ongoing threats, and providing emergency food and shelter (Tierney, Lindell, & Perry, 2001).

The focus in the response phase is on meeting the basic needs of the people until more permanent and sustainable solutions can be found. Humanitarian organizations are often strongly present in this phase of the disaster management cycle (Srinivas, 2010).

3. Recovery Phase and Reconstruction Phase

Recovery activities continue until all systems return to normal or better. Recovery measures, both short and long term, include returning vital life-support systems to

minimum operating standards, temporary housing, public information, health and safety education, reconstruction, counseling programs, and economic impact studies (Srinivas, 2010). During the recovery phase, debris clearance is usually completed, essential services are completely restored, insurance claims are filed, preliminary reconstruction plans are designed, and a sense of normalcy begins to return to the community. The reconstruction phase begins after the recovery phase and may, depending upon the scope of the disaster, extend for years (Fischer, 2008).

Over the years, this neat picture has been replaced by a continuum of activities and phases managed by the humanitarian community and development organizations. Figure 2 depicts the overlapping characteristics of the different phases in disaster management. The numbers from -1 to 4 on the left side of the figure denote generic time periods of a natural disaster. For example, -1 denotes the time period before the happening of natural disaster, 0 denotes the sudden happening of natural disaster, 1 and 2 denote the response phase and 3 and 4 denote the phase of recovery and reconstruction. Overlapping activities during each phase can be seen very easily with the help of Figure 2.

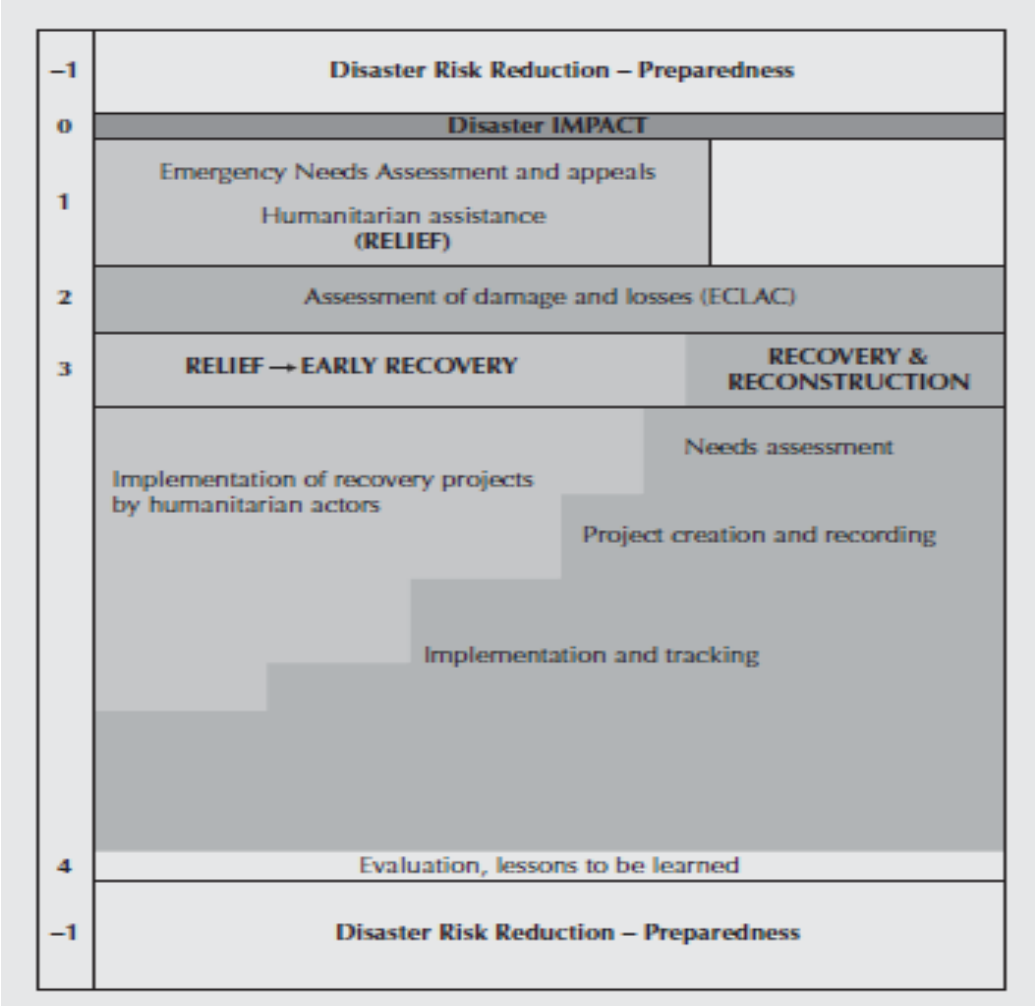

Figure 2. The Overlapping Phases in Major Recent Disasters (From: Data Against Natural Disaster, Amin & Goldstein, 2008)

B. COMMERCIAL SUPPLY CHAIN MANAGEMENT

As the globalization process gets faster and the customers become more conscious, competition increases. This fierce competition forces entrepreneurs to find new ways of doing business. A couple of great ideas (e.g., six sigma, lean methods) were found that use technology and statistics to increase the operational efficiency within a company. But companies like Wal-Mart showed there is still room to increase efficiency while decreasing the cost at the same time. This is done by implementing a total systems

approach to managing and coordinating the entire flow of operations, information, materials, and services from raw materials suppliers through factories and warehouses to the end user (Jacobs, Chase, & Aquilano, 2009).

The supply chain can be thought of as a network, which consists of a Supplier-Vendor-Customer cycle using factories, distribution centers and retailer stores. This cycle first converts raw materials to products and then to the market money-equivalent of that product. The main idea behind supply chain management is increasing the service level or decreasing costs or both at the same time, thus increasing the efficiency as much as possible. In this situation, we can think of cost in a broad sense from a system-thinking perspective as the monetary value of all raw materials bought, overhead costs, labor added and time spent by an entrepreneur in a market to produce a product or a service, with the purpose of making revenue by selling it.

Before implementing a supply chain strategy, an organization (profit or non-profit) should know the fundamental aspects of supply chain management. Because, although the aspects of supply chain or business management like transportation, storing, and manufacturing look alike, every industry (and perhaps every product) needs a different implementation and formula. There are many ideas and important aspects of supply chain management. But given that our goal is to implement these aspects in disaster relief operations, we thought that the most important concepts that support supply chain management, and thus of prime concern to our project, are information technology and information sharing, global optimization, partnership and uncertainty.

1. Information Technology and Information Sharing

A supply chain is a network in which many companies cooperate to deliver a product to a final customer by using transportation and an information infrastructure across the world. Without transportation and the information infrastructure, it is not possible for different companies to operate together, and without companies it is not possible to produce final products and deliver them to the final customer. We can use an operating systems layer analogy to show this dependency in the logistics network.

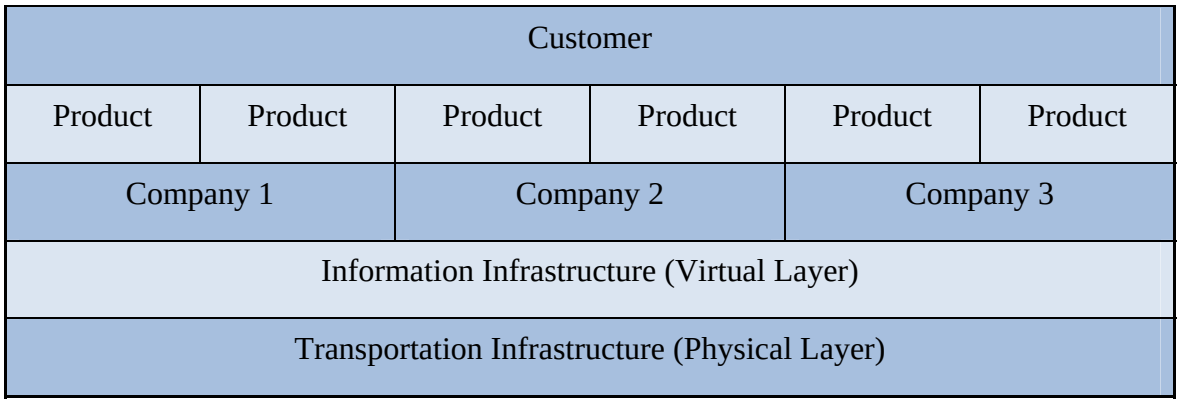

Figure 3. Supply Chain Layers

Figure 3 shows the vertical interaction that occurs in a supply chain. Different companies produce different products by using transportation and the information infrastructure. Without this infrastructure, it is not possible for a company to operate. In a market, buyers and sellers interact; this interaction happens via the products and today the role of seller is usually played by a company. Also, we can say that there is an interaction between companies and one company is a buyer for another company in the supply chain flow from raw materials to finished goods. But at the end, on the buyer side, the number of individual customers is higher than the number of corporate buyers. Also, we cannot discuss a product without having a company that supplies it and there is no value of a product if there is no customer who is willing to buy it. At the end, customers, products, companies and infrastructure are all part of the supply chain and they are all necessary because of their relationships with one another.

Information technology has wrought great benefit for companies. For example, it made sharing information with partners very cheap and easy. One of the most important problems for many companies is lead times. To reduce the lead times, sharing up-to-date data produced by different actors in the logistics network is essential. Technology not only made information sharing easier but also helped to create new management systems for companies. For example, many times ERP systems help increase the efficiency within and outside the company. But a company should be very careful while investing in technology. Buying cutting-edge technology does not always mean a quick and easy way

of increasing efficiency. For example, in the late 1990s some companies who thought Internet and e-business models would solve their supply chain problems failed (Simchi-Levi, Kaminsky, & Simchi-Levi, 2007).

2. Global Optimization

Global optimization seeks to find the most effective system-wide solution for operational problems within the capabilities of the actors enabling the operations. The supply chain is a complex network of facilities dispersed over a large geographical area and, in many cases, all over the world (Simchi-Levi, Kaminsky, & Simchi-Levi, 2007). But, as mentioned before, information technology changed many things in our lives. Today, we can solve many hard mathematical problems much more easily and we can allocate our resources not only according to educated guesses or experience but also using mathematical solutions. We can think of each actor in the supply chain—supplier, manufacturer, distributor and retailer—as a node for an optimization problem to enhance the best logistics solutions for our business strategy.

3. Partnership

Supply chain management emphasizes collaborative relationships between buyers and suppliers within a supply chain (Ryu & So, 2009). In a traditional supply chain, each party focuses on its own profit and makes decisions with little regard to their impact on other actors (Simchi-Levi, Kaminsky, & Simchi-Levi, 2007). Data sharing is one of the most important enablers of a supply chain. Besides that, for an effective supply chain some investments may be needed. How to share the cost of these investments across a benefit-associated partnership to all players might be unclear at first. These are some of the difficulties, but applying a long-term partnership that satisfies the basic objectives of all the actors is needed. The necessary coordination can be established by negotiating and showing the benefits to all parties or, sometimes, by the most powerful actor within the network pushing for a minimum coordination level.

4. Uncertainty Problem for Companies

The most critical problem for a company is diminishing the uncertainties. Uncertainty has two dimensions: one arises from demand and the other from supply.

a. Demand Uncertainty

Using effective forecasting methods is important to decrease demand uncertainties. When we apply a supply chain strategy, the uncertainties become more complex. Every node in the network wants to secure itself, so whenever they order they add some safety stock to accomplish their service level; this means unnecessary inventory is being built in each node. Sometimes, usual practices in business like promotions make the situation worse. Sellers want to hike up the revenue and offer promotions. Retailers respond to these promotions by stocking up. Nobody wins in these deals, because the seller does not know the real demand and the buyer builds excess inventory (Lee, 2002). And, as the number of actors increases in the network, the variability increases and makes it very hard to forecast the real demand of the end-user. This phenomenon is called the bullwhip effect. Information sharing and partnership is critical to deal with the bullwhip effect in a supply chain.

b. Supply Uncertainty

Often a manufacturer uses many different raw materials to produce a product. Nowadays, every one of these raw materials comes from different suppliers around the world. Think about an earthquake striking one of your critical suppliers. What can you do to continue production? Every company takes into account these probabilities and builds safety stock for emergencies. Building up inventory may not be the only solution to this problem in the competitive environment. Risk pooling is another supply chain tool for a company to use to deal with variability.

In both case, companies are building inventories to deal with uncertainty. We cannot eliminate all the uncertainty but, by using effective methods in supply chain management, one can decrease the inventory level. Inventory turnover rate is an important measure to evaluate the supply chain efficiency.

As we said earlier, there are no universal solutions for companies. Every product, every industry has some unique aspects. For example, according to different product characteristics, Hau L. Lee (2002) defined four different supply chain strategies: Efficient, Risk-Hedging, Responsive, Agile Supply. We will consider these differences when we apply supply chain management to disaster response activities.

C. HUMANITARIAN LOGISTICS

Entrepreneurs have a motive to make money when they manage their business. In humanitarian operations, the motive is to save lives and help people. Although companies and humanitarian operators have different goals, the operations they manage involve some similar concepts. For this reason, this section will start by treating the notion of humanitarianism, and then present the logistics function as a central function in disaster relief operations and define the field of humanitarian logistics.

1. Principles of Humanitarianism

One of the aftermaths of the battle of Solferino in 1859 was the establishment of the principles of the humanitarian action by the Swiss Jean-Henry Dunant, who sought to protect the rights of wounded soldiers on the battlefield and provide them the required care regardless of which side they were on. In developing this rule, Dunant articulated the three principles of humanity, neutrality and impartiality. These principles were widely adopted in the 1864 version of the Geneva Convention to protect the rights of the wounded and sick on the battlefield, and were also the origins of the Red Cross movement which started in 1875.

A brief explanation of the meaning of these three principles will be very important for defining the environment in which humanitarian operations are conducted. In fact, these three principles are explained as follows:

- **Humanity**: This principle means that wherever it exists, there is a duty to relieve the suffering of any group of humans affected by disasters and bring them aid and assistance.

- **Neutrality**: This principle implies that the operating actors must maintain a neutral stance in their activity. Any kind of affiliation to a local or international organism is refused and it is mandatory to avoid being trapped by any political agenda.
- **Impartiality**: This principle indicates that aid and assistance must be provided without discrimination in regard to the most urgent needs. Priority must be given to the neediest and the most exposed to risk and damage.

These principles are much more than moral guidelines for humanitarians in their actions, although they were adopted at the beginning for a special kind of crisis, armed conflict, and a special kind of affected population, wounded soldiers. The developing field of humanitarian relief extended the adherence to these principles to all humanitarian operations, whether the crisis is natural or man-made. The great majority of today's humanitarian organizations, such as the United Nations High Council of Refugees, the World Food Program or the Red Cross, observe the above-mentioned principles in their agendas, policies, decision-making processes and operations. These principles represent the boundaries of the environment in which they operate and define the notion of the humanitarian space. Indeed, this notion exists in two dimensions, the virtual and the physical:

- The virtual dimension is defined as follows: "In the virtual sense, humanitarian space represents the interaction between the different members of the humanitarian ecosystem and how they create an environment where their mandate can be executed" (Tomasini & Wassenhove, 2009). This definition is very important in that it makes clear two facts:
  - The existence of a network of different actors working for a humanitarian purpose and having mutual influence on each other.
  - The existence of an ecosystem where humanitarian actors create the proper environment to execute their mandate.

- The physical dimension is defined as follows: “in the physical sense, humanitarian space represents a zone where civilians, non-combatants, and aid workers are protected from violence and attacks and can move and operate freely” (Tomasini & Wassenhove, 2009). This definition focuses on the terrain security issues that humanitarian organizations face during the execution of their mandate but does not include another set of constraints that affect their work, like transportation routes and movement inside the affected zone. Therefore, we will consider that in the physical sense humanitarian space is the physical environment in which the humanitarian actors operate and move.

The main objective of the humanitarian actors is to establish an adequate environment where they can operate with respect to the humanitarian space. This will add much more burden on their task and especially on their logistics operations.

2. Humanitarian Logistics

Most natural disasters are plagued by limited reliable information, an overwhelming sense of urgency and many local and external complexities that affect these operations. Preparedness is conceived as the optimal solution that can significantly improve these issues since successful responses are not improvised. Disaster management is defined as “A combination of preparedness and response. Preparedness addresses the strategy put in place that allows the implementation of a successful operational response in the theater” (Tomasini & Wassenhove, 2009).

The pre-established preparedness strategy for an emergency response is built around five major pillars: human resources, financial resources, knowledge management, collaboration between key players, and logistics. These pillars are set to create a agile humanitarian supply chain that is adaptable and aligned enough to support and serve the emergency response.

Over years, workers in the humanitarian field arrived at the conclusion that most failures in disaster response were due to a failure in logistics, which is recognized as the essential element in relief operation; “the response to most disasters is comprised of 80

percent logistics considering numbers of activities, fund allocated and skills requirement" (Tomasini & Wassenhove, 2009). Thus, logistics is seen as a central function in disaster response that leads and organizes a whole bunch of activities like transportation, warehousing, and pushing inventory to the front line. It is distinguished from logistics in the commercial sector due to its specific mission and has its own definition regarding its role in disaster response and the nature of the field complexities.

3. Humanitarian Logistics and Supply Chain Management

During the few last years, the conceptual evolution of the logistics and supply chain fields, as independent disciplines, made them beneficial for disaster relief operations in term of efficiency, cost saving, decreasing excess supply, and dealing with uncertainty of demand. These operations have seen a huge improvement in coordinating activities and solving problems generated by the erratic situation of the environment. A new specialized field of study appeared—humanitarian logistics.

This recent field is defined as "the special branch of logistics which manages response supply chain of critical suppliers and services with challenges such as demand surge, uncertain suppliers and critical time windows in face of infrastructure vulnerabilities and vast scope and size of operation" (Apte, 2010). As a result, humanitarian logistics are seen as "a supply chain of spanning the life cycle of a disaster" (Apte, 2010).

Therefore, humanitarian logistics is the branch of logistics specializing in organizing required logistical activities during disaster relief operations or complex emergencies. This branch distinguished itself from commercial logistics and military logistics because of the operational constraints characterizing the humanitarian space and the different issues and challenges faced.

4. Humanitarian Logistics Characteristics and Specifics

Seen as a responsive supply chain process, the model of the humanitarian logistics network depends on the following factors: customers, demand, supply, inventory, flow, lead time, and the distribution network.

Inherently, the customer in the commercial supply chain is located on the final edge of the network, opposite the humanitarian supply chain that admits two customers located on both sides of the network. The notion of customer is not limited, in this case, to the population affected by the disaster and expecting aid, but includes also the donators who expect that their donation will reach the needy.

The demand is characterized by great unpredictability in term of quantity, and supply types comprise a short list but have a great deal of challenges associated with them since they are provided through donations. This will generate a high level of inventory because of the unpredictability of demand and the long delivery time. The long delivery time is also an origin of the perishability of goods issue.

The infrastructure, already vulnerable because of the effects of the disaster, combined with the uncertainty of acquisition of necessary supplies, generates a disturbed pipeline where the flow is not permanent. The required lead times are short but longer lead times are induced due to the problems of collecting useful information and coordination between the different members of the network.

Finally, for humanitarian logistics, the distribution network is very dynamic and falls under the influence of the affected area infrastructure; it is difficult to reconfigure due to the relatively large number of players involved. The major concern in the distribution network is the last mile where many bottlenecks slow the flow and may stop the distribution process entirely.

III. COMPARATIVE METHODOLOGY BASIS

In the response phase of a disaster, the focus is first on actively managing the efforts to save lives, and then on meeting the needs of survivors. In this phase, you are fighting with time and nature to save as many lives as possible.

There are not any globally defined rules and activities in the response phase. We believe that some general definitions and standards will arise as the field of disaster management develops. Currently, however, it seems best for an organization that analyzes or builds a structure for the response phase to apply the FEMA response definitions. FEMA is one of the most-recognized, best equipped, best-funded public emergency management system and, by all measures, is the leading public emergency management organization in the world. It developed a National Response Framework especially taking into account the lessons learned from Hurricanes Katrina and Rita (Haddow & Bullock, 2003).

In this chapter, we will first define both general and logistics-related activities in the response phase to better understand what is happening in the theater (area that the disaster affected). We believe that when we define the logistics activities, we can use commercial experience to establish performance metrics by using the supply chain approach. The reason we also mentioned general activities together with logistics activities is that these activities sometimes directly, sometimes indirectly affect the performance of logistics activities. In Chapter II, we said that without enough preparedness, the response efforts will be ineffective. In our project, we will assume that the necessary activities were done properly before the response phase. So, we assume that there is an operational plan, pre-established team structure, transportation deployment plan, fuel and food distribution and storage centers.

In the second part of this chapter, we will define the factors that will affect the scope of the response activities. Even disasters of the same type can result in different

types and levels of needs (demand) and require different types and levels of support (supply). Lastly, we will introduce our performance metrics to evaluate effectiveness of logistics activities during the response phase.

A. RESPONSE PHASE

Response activities include establishing a command and control center, rapid initial assessments, search and rescue, providing medical aid, food and water, and emergency sheltering. The aim of emergency response is to provide immediate assistance to maintain life, improve health and support the morale of the affected population. Such assistance may range from providing specific but limited aid, such as assisting refugees with transport, temporary shelter, and food, to establishing semi-permanent settlement in camps and other locations (Warfield, 2010).

The type of the activities applied in the immediate response will depend on the nature of the disaster and the effectiveness of mitigation measures, but is also very much conditioned by the degree of preparedness achieved. According to Figure 4, initial rapid assessment, search and rescue, and providing medical aid, food and water are the fundamental activities performed during the immediate response phase, which can take days or weeks according to the type of the disaster.

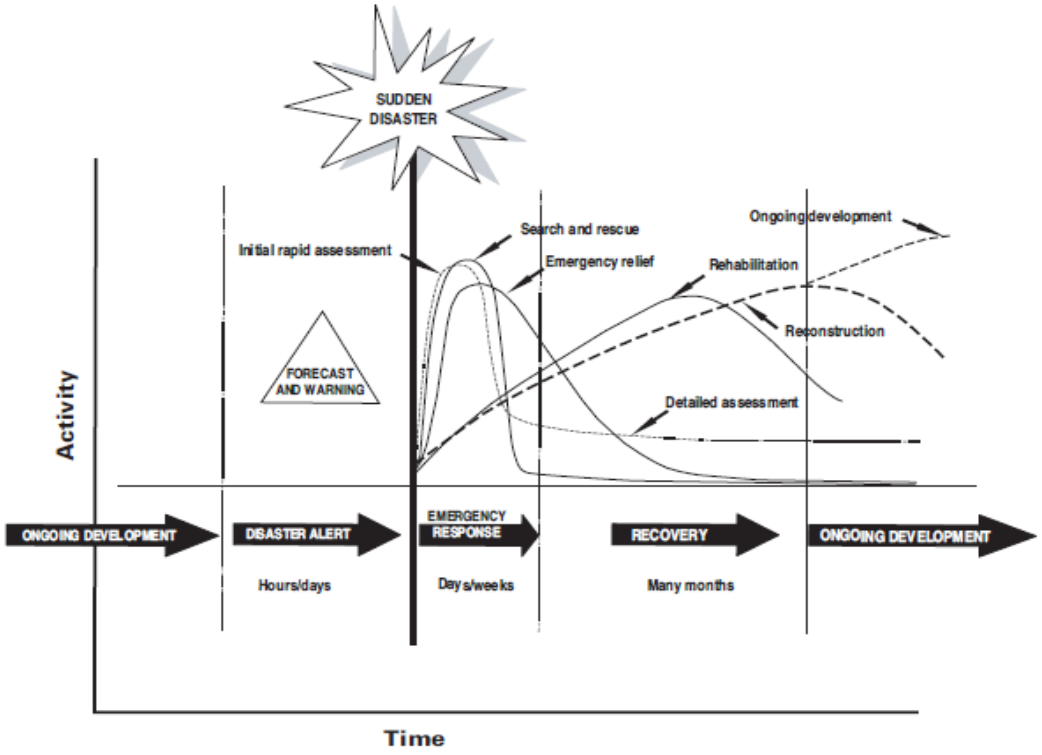

Figure 4. Activities During a Sudden Disaster (From: Environmental health in emergencies and disasters, Wisner & Adams, 2003)

Now, we will explain all these five activities with their logistics requirements.

1. Establishing the Command and Control Center

When a disaster strikes, our normal life routine is suddenly disturbed and an emergency situation emerges, which we can describe as chaotic. In this chaos, responders have to mobilize people and equipment, and coordinate activities to return to normal life as fast as possible. As the magnitude of the disaster gets bigger, managing activities in this chaos gets harder. The activities in response operations have to be managed by a central authority to coordinate the efforts effectively. Some kinds of disasters, such as volcanic eruptions or hurricanes, provide advanced warning so you can prepare; in other cases, such as earthquakes or landslides, it is very hard to know ahead of time when they will hit. In both cases, we have to establish a command and control center to coordinate the response activities and to enable information sharing. The only difference between

these situations is that a command and control center may be established somewhat sooner in the first case. So, we will include establishing the command and control center as an activity of the response phase.

A difficult issue in this activity is determining who is in charge of the overall response effort. The main function of this activity is establishing a set of planning and management systems that would help the agencies responding to a disaster to work together in a coordinated and systematic way (Haddow & Bullock, 2003).

Leadership is a crucial part of management after the command and control center is established. Usually, the most senior manager in the local government will take the leadership role. However, managing a local government and an emergency situation requires different leadership characteristics. If the local leader cannot manage the operations effectively, all activities will be affected badly and limited resources will not reach the victims in time.

There will be many problems when first operating with different actors. There will be many actors with different cultures and objectives. Power struggles will trigger miscommunication and create duplication of efforts. In the virtual humanitarian space, the decision-making process will be affected by the level of information sharing and connectivity of the actors. Creating a structure that supplies adequate information flow in a command and control center will affect the responsiveness of all activities. Another issue addressing information sharing is feeding up-to-date information to the outside world.

Establishing coordination mechanisms in command and control centers is vital for effective communication and synchronization of logistics activities. In large disasters, there will be many local and international NGOs, each of which will have a particular skill or offer a special service to victims. A coordinated effort would yield more efficient operations since a lack of coordination can cause a slower reaction and inaccurate assessments in an environment where urgent decisions are needed.

2. Emergency Assessments

There are two types of assessments conducted during the response phase of the disaster life cycle: the rapid initial assessment to establish the nature and scale of the emergency and the likely need for external assistance; and detailed sector assessments to plan, implement and coordinate a response (Wisner & Adams, 2003). Generally, an emergency situation and needs assessment should be conducted during the first 36-72 hours. Rapid initial assessments should be conducted in order to establish the nature and scale of the emergency and the likely need for external assistance.

Organizations involved in emergency response should assess the emergency situation and choose their objectives before implementing response activities. Organizations that provide relief without first assessing the disaster impact, the resulting needs, and the local response capacities will most likely offer assistance that is unnecessary and inappropriate and which supplants local efforts. Ideally, an emergency response should consist of the following three stages: assessing the situation, choosing objectives and identifying intervention alternatives, and implementing a response based on the objectives and alternatives (IFRC, 2000).

Assessments often begin with a brief review of information about the area and the population affected the type of disaster, and the environmental health infrastructure that may have been affected. Accurate information on disasters such as floods may be rapidly available from satellite images of the affected area. When combined with preliminary information from the disaster area, this can provide a rapid overview of the situation and an indication of likely damage and needs. In some cases, it may be possible to start organizing an initial response on the basis of this second-hand information (Wisner & Adams, 2003).

It is most important to work with local partners and government agencies to ensure that assessments seek to find information that is not already available and that information gathered is shared with interested parties. According to the Disaster

Emergency Need Assessment report of the International Federation of Red Cross and Red Crescent Societies (IFRC), the following questions should be answered with the rapid initial assessment.

- Number of affected people requiring assistance
- Water needs
- Shelter Needs (through housing and clothing)
- Nutritional needs
- Sanitation needs
- Fuel needs (for cooking and heating)
- Health care needs

A detailed sector assessment is necessary to plan, implement and coordinate a response. A satisfactory detailed sector plan can only be formed with an effective initial rapid assessment. Because of that, assessment is the fundamental factor that affects the other factors.

3. Search and Rescue (SAR)

The aim of SAR is rescuing the greatest number of people in the shortest amount of time and rescuing first lightly trapped victims. Experience from previous disasters has shown that immediately after almost every disaster, the first response to trapped victims is by spontaneous, untrained, and well-intentioned persons who rush to the site of a collapse in an attempt to free the victims (Human Technology, n.d.). But after a disaster hits and the disaster response efforts start, professional SAR operations by dedicated task forces begin immediately. The first task forces usually will be local task forces; after that, and according to the disaster's magnitude, international task forces will begin operations.

Professional SAR operations need expertise, special equipment and training. The other important characteristics of SAR operations that the team should take into account are the humanitarian principles of humanity, neutrality and impartiality. Task force members must hold the following specialist skills: technical search, rescue, emergency medicine, structural engineering, logistics, communications, canine search, and hazardous materials handling. The SAR task forces will be the first agents of disaster

response organizations in the theater and the first users of the inadequate information and transportation infrastructure. They will both assist the people and provide critical local information. For effective and efficient SAR operations, mobilizing the right teams in the right place is critical. Different types of disasters need special SAR expertise. The prompt receipt of all available information is necessary for a thorough evaluation of the situation, immediate decision on the best course of action, and timely activation of SAR facilities. Planning and coordination of SAR is also the beginning of the overall coordination of response operations.

Although the terminology used varies among organizations, SAR operations are generally accomplished in four phases: the uncertainty phase, the alert/search phase, the rescue/recovery phase, and the termination phase (Inter-American Development Bank, 2001). The uncertainty phase is said to exist when there is knowledge of a situation that may need to be monitored, or to have more information gathered, but that does not require dispatching of resources (The National Search and Rescue Council, 2009). In natural disasters, the uncertainty phase is not so important because it is often generally known which area(s) was hit by the natural disaster.

The alert/search phase includes full notification to all emergency response agencies and the initiation of a full communications search using available resources. A control center is established and extensive coordination of planned search activities is required to avoid duplication and ensure best utilization of the various types of equipment and personnel available (Inter-American Development Bank, 2001). In natural disasters, we can assume that a local or international authority is alerted by a request for emergency help. Also, the control center of SAR activities should be a part of the relief operations' general command and control system. A coordinated and informed notification system is important to utilize inadequate recourses, infrastructure and manpower in this phase. According to FEMA, local task forces must be able to deploy all personnel and equipment within six hours of activation, and must be able to sustain themselves for the first 72 hours of operations

The rescue/recovery phase begins with the identification of the location of the wreckage. Today, modern technology provides essential tools to specify the geographical

coordinates of the disaster, most notably Global Positioning System (GPS) equipment. During the rescue phase, the mission is the saving of lives and extraction of the victims as rapidly and efficiently as possible. The control center must coordinate and direct all activities towards this goal, taking into account the availability of specialized and often inadequate resources such as medical response teams and teams with special equipment such as chainsaws or excavating equipment. Additionally, the control center must insure that preparations are made to receive the victims upon their arrival, perform such on-site aid as is necessary and available, and transport the victims to the designated treatment location (Inter-American Development Bank, 2001). Speed is critical in this phase because, according to the survival law of 3s, a person can live only three minutes without air, three days without water, and three weeks without food.

The recovery phase begins when it is determined that the rescue is complete or that there are no more survivors. This phase is not as time sensitive as the rescue phase. The first priority in this phase is the recovery and transportation of bodies and/or body parts. The later recovery of the wreckage is often a sensitive issue as the wreckage must frequently be left in place until the official accident investigation team approves movement. The location and condition of the wreckage is a vital factor in determining the cause of the accident.

The termination phase starts with notification to all participants that search and rescue operations are no longer required. This phase includes the extraction of the personnel and equipment used in the operation.

In search and rescue operations, there are two important customers. First is the SAR task force. Support of the task force is important because they are the most important people who increase or decrease the number of survivors. Task forces usually have their own equipment, but after mobilization it is essential that the task groups coordinate and supply the needs of the group. Table 1 shows how a planner or coordinator should be evaluating the logistics support of the task forces in a command and control center. The second customer is the rescuers, who need resources to perform

initial medical care and transport these people to the right places. The number and condition of survivors will affect other response activities and will change demand for transportation, shelter, and supplies to meet basic needs.

Table 1. SAR Planning Questions (From: Bennett, Disaster—Light Search & Rescue, 1992)

Resource	Planning Questions
Personnel	▪ Who lives and/or works in the area? ▪ During which hours are these people most likely to be available? ▪ What skills or hobbies do they have that might be useful in search and rescue operations? ▪ What might be the most effective means of mobilizing their efforts?
Equipment	▪ What equipment is available locally that might be useful for search and rescue? ▪ Where is it located? ▪ How can it be accessed? ▪ On which structures (or types of structures) might it be most effective?
Tools	▪ What tools are available that might be useful for lifting, moving, or cutting disaster debris?

4. Providing Basic Needs

Providing food, water, and other necessities to meet the needs of all disaster victims, including persons with disabilities and other special needs, is a part of the response phase activities.

Engineering, financing, contracting, establishing security, sanitation, food safety, and other logistics and management functions are the essential tasks to meet basic needs. But in terms of the logistics network, medical care and supply of food and water are two essential tasks of a response operation.

a. Medical Care

Providing medical care and triage is one of the most important activities of the response phase. We can divide medical care into the theater level and the hospital level. In the theater level, the paramedics will help the people who are rescued by the SAR teams and the people who have minor injuries. To be able to help the victims of disasters, paramedics have to have some kind of emergency supply kits like the SAR teams. The first aid performed in the theater level may include applying bandages to stop bleeding, treating shock, and setting broken bones. It could also include giving medicines and intravenous fluids. After or while the patient is being stabilized, if it is needed, the paramedics will transport the individual to the hospital (Mcentire, 2007). This will create a demand for transportation within the operational area, the scheduling of which is another problem beyond the paramedics and should be coordinated with the coordination center. Another issue in this level of medical care is supplying emergency medical goods to paramedics, which also requires transportation. The health providers are also, like SAR teams, data sources that help manage the disaster better.

At the hospital level, the injured people will be treated according to their wounds and the capability of the hospital. A second level triage will be held in this phase and the injured people who are beyond the capability of the hospital will be transformed to another facility. High levels of communication and coordination through the rapid assessment, monitoring and surveillance activities will increase the service level and will decrease lead times needed to assist the victims. Actually, a kind of health network will be established during this phase and will be part of the overall supply chain. Determining how the health services network will function in disasters involves identifying what facilities are key to meeting emergency needs, taking into account their level of security, complexity, available human resources, strategic location and specialized services. The functionality of these key areas must be guaranteed if the health sector's emergency response plan is to be successful. For this to happen, the level of damage they sustain must be minimized (News and Information for the International Disaster Community, 2001). To minimize the damage, these facilities should be a priority for initial engineering and logistic services. Every hospital should maintain a stock of emergency

medicines and supplies, but supplying the needs of hospital and health providers should always have the priority. This is because, as time passes, collecting dead persons, poor sanitation, inadequate food supply and shelter will increase the vulnerability of survivors to communicable diseases.

Both at the theater and hospital levels, keeping a record of deaths is important. In the case of insufficient cold storage, burying the deceased as soon as possible is mandatory to maintain sanitation and prevent communicable diseases. When the recovery phase begins or even in the response phase, people will begin to search for their relatives and lost people will increase the burden of disaster in the society.

b. Providing Food and Water

Access to food, water and maintenance of adequate nutritional status is a critical determinant of persons' survival in the initial stages of an emergency. Malnutrition can be the most serious public health problem and may be a leading cause of death, whether directly or indirectly (The Sphere Project, 2000). At the beginning of the response phase, the most important activities to increase the number of survivors are SAR and immediate health care, but as time pass SAR activities will decrease and the health-care need will stabilize. From this point to the beginning of the recovery phase, providing basic needs will begin to dominate the response operations. Providing for the basic needs of many people in a short time is an enormous logistics operation for a supply network.

With the exception of specific cases of population displacement where people probably have no access to food at all, disaster-affected populations are often able to find part of their own food supply from their own resources. No practical assessment technique exists that can discriminate precisely between the different food aid needs of households within a population (The Sphere Project, 2000). This makes the forecasting of the required amount of food much harder, and in many cases impossible. The data provided by SAR teams and in-theater health providers, together with historical data, will help the control and coordination center assess the need. Poor estimation will cause either insufficient or excess food. Insufficient food, as noted earlier, causes health problems and also creates a security problem.

5. Emergency Sheltering

Emergency shelter may be required for those whose homes have been lost or damaged. After sudden disasters within limited areas, or where relatively few people are displaced by conflict, people generally house themselves. They find accommodation with neighbors or family members, or make temporary shelters within the ruins of their former homes. They will usually have found accommodation long before relief teams have begun to provide tents or other help. People are generally very reluctant to move away from their neighborhoods following such a disaster. However, in extreme situations (e.g., very cold weather, the threat of explosion or toxic gas, possible secondary flooding or mass movement of debris) survivors should be evacuated (Wisner & Adams, 2003).

During the immediate response phase, a great importance should be given to the emergency sheltering efforts, especially for those victims who do not have the capability to find themselves temporary housing or shelter. According to the GAO report "Better Planning Needed for Housing Victims of Catastrophic Disasters," the emergency sheltering efforts are intended to provide:

- mass care, including sheltering, feeding, and emergency first aid
- housing, both short and long term
- human services, such as counseling, processing of benefits, and identifying
- support for persons with special needs

B. FACTORS AFFECTING THE LOGISTICS NETWORKS

The objective of this section is to determine what factors affect the establishment of a logistics network supporting a disaster relief operation. When examining these factors, a fundamental distinction appears between two categories of factors: external and internal factors .The external factors such as financial support, volume of donation, number of actors and people participating in the operation, and international support come in response to the requirements of the field situation. Drawing the necessary network and planning for operation are in fact mainly driven by the internal factors that

are the results of the disaster. The real challenge for the response phase is to establish an efficient field assessment that is easy to convert to logistics requirements through a study of this second category.

For this purpose, we will try to identify these internal factors, understand their impact, and determine the interactions between them to be able to build a consistent assessment. Four factors are identified: the affected population, the affected area, the level of damage and the potential threats.

1. Affected Population

The affected population is the group of individuals present in the location where the disaster has struck and which is suffering from its effects. Generally used to describe injured or killed individuals, the word “victim” can be used to designate the affected population whatever physically harmed or not. In fact, a victim is an individual suffering under the effects that can also include loss of property and potential exposure to diseases and epidemics.

As a basic factor influencing operations, the affected population is characterized by many parameters. In fact, the global number of people affected by the disaster is not itself sufficient information if it is not linked to qualitative parameters capable of categorizing the victims. This categorization is not limited to the different levels of injuries, but must encompass many other parameters, including the initial location of victims, their ability to move inside the affected area and their behavioral reaction.

- Number of victims: the number of victims can vary from a few hundred to millions of people, depending on the strength and the magnitude of the disaster. It is one of the principal factors that will determine the required resources allocated for the disaster relief operation and as a result the logistic network supporting it.

- The levels of injuries: The degree of health affliction varying from death to dangerous injuries to medium injuries to mild injuries or no injuries. This characteristic is necessary to identify the nature and volume of medical assistance, the required medical facilities and the necessary resources for evacuating victims, if necessary.
- Location of the victim: The success of response depends on being in the right location at the right time. That is why locating victims is an essential process for relief progress. Locating victims is obviously the first action undertaken by responders in the theater of operations.
- Ability to move inside the affected area: This characteristic refers to two complementary notions, mobility and level of entrapment of victims. The level of entrapment is defined as the difficulty encountered by the victims when trying to move outside locations where their safety is endangered and/or where the remaining infrastructure after the disaster does not permit them to survive. At the same time, mobility does not refer only to the ability of the victims to move across/outside the disaster area, but includes the notion of choosing the most suitable and adequate mean of transportation necessary to move the population, to transport aid, to deploy rescue teams and to conduct operations. The ability to move inside the affected area is important as it constitutes the first factor used to estimate the demand of transportation and the required resources that must be allocated to meet this demand.
- Behavioral reaction: The reaction of the affected population after the disaster has a lot of influence on relief operation management. On one hand, the affected population can improve resources for the relief operation by providing various information and participating in different relief activities. The knowledge of the terrain and the will to rescue their entrapped fellows as soon as possible and to treat the injured are the motivations for this reaction. On the other hand, the intensity of the shock generated by the disaster events and the collective panic can turn the

victims into the origin of various bottlenecks in the relief network. Behavioral reaction can be evaluated in term of three components: communication abilities of the affected population, its level of cooperation and finally goals of the affected population.

2. Affected Area

Defining the affected area is necessary for the relief operation efforts because it determines the extent of the disaster's impact on the ground and limits its boundaries. It is also important because it determines the physical environment of operations. The affected area represents the physical space where disaster relief operations occur, which means that it is not limited to the disaster area but includes the area generally surrounding the location of victims from which responses are conducted or to which affected the population is flowing in search of safety.

The affected area can be an urban area or a rural area or includes both urban and rural affected regions. This distinction is important because the density and distribution of population, as well as the route network and infrastructure are parameters that will affect the course and nature of operations. Every kind of environment, urban or rural, has its own set of problems and issues affecting relief operations and demanding a different use of resources, different deployment plans and different logistical planning. The affected area has four characteristics: size, traversability, survivability and safety.

- Size: the physical space of the affected area. The effect of the disaster is not uniform in the affected area, which means that some sections will be more affected than some others. To be more informative, it is possible to divide the affected area into sections or locations according to their physical size and the level of damage.
- Traversability: the possibility of use of the routes and the remaining transportation infrastructure after the disaster by the relief teams and the affected population. The traversability of the affected area depends also on the mean of transportation that can be mobilized during operation.

- Survivability: the ability of the remaining infrastructure after the disaster occurred to maintain the affected population in a relatively decent condition. Survivability can vary from one section to another in the affected area but it is very important to decide how and why to move the affected population.
- Safety: the level of protection from threat that the affected area or some location in the affected area can provide.

3. Level of Damage

Specialists have tried to establish normative scales able to measure the magnitude of disasters. One successful and common example of these measurement systems is the Richter scale. Created to measure the magnitude of earthquakes, this scale assigns a single number to quantify the amount of seismic energy released. Another example is the Saffir–Simpson Hurricane Scale, established to classify western hemisphere tropical cyclones that exceed the intensity of tropical depressions and tropical storms.

Although widely used, these scales and so many others cannot really provide a detailed description of the level of damage unless a contextual definition of it is provided. The level of damage, according to this study, will be defined as the extent to which the disaster has deteriorated the situation of the affected population in the affected area. We will judge the damage generated by the disaster according to the impact on the two sets of parameters mentioned above to describe the affected population and the affected area. These parameters are:

- The number of victims, their levels of injuries, their location, their ability to move inside the affected area, their behavioral reaction - including communication abilities, level of cooperation and goals
- Size of the affected area, its traversability and the survivability and safety inside the area

The level of damage will describe the initial situation right after the disaster struck but is not static; it evolves over time. As a matter of fact, there is a definite need to identify another factor in the upcoming situation; this factor will be the potential threats.

4. Potential Threats

Potential threats are defined as the possible events that can occur following the primary event and would deteriorate the initial situation and disrupt the relief operation by adding more burdens on the initial required activities or simply prevent them. They can also be defined as the possible future levels of damage of the affected area and the affected population.

Potential threats are not restricted to the natural disaster secondary events, like mudslides accompanying flood or secondary seismic waves, but can be also manmade events like acts of looting inside the affected area, unpredictable movements of the affected population due to a panic reaction, which creates congestion in the remaining practicable road system. It can be also a high risk of contagious diseases or epidemics due to the deteriorating sanitary conditions in the affected area. Potential threats must be considered as the future situation that may take place in the affected area.

C. PERFORMANCE METRICS

So far we have described what happens right after a natural disaster strikes. An enormous effort begins involving governments, international organizations, militaries and commercial companies who begin to work amid chaos to achieve their goals. The main goal in the response phase of disaster management is basically to save as many lives as possible. But today we know from management science that it is necessary to evaluate your overall performance to understand how well you achieved your goal with your limited resources. A strong preparedness is essential to save as many lives as possible when a natural disaster strike but it is equally important to manage the response operations effectively for the same objective.

Today in the commercial sector a new kind of thinking fostered greater performance for many companies. We mentioned the component of this new approach, supply chain management, in both the commercial and humanitarian sectors. Our objective in this part is to establish performance metrics using the supply chain approach for response activities to help management of disaster response operations.

We consider the response phase operations to be products produced by an unseen company and our goal is to leverage the benefits of success practices of the commercial sector. The operations center that is established right after, or in some case right before, a natural disaster strikes is the headquarters of this company. The activities defined mainly in Section 1 are the products and services of this company. These products and services are SAR, sheltering, and meeting the basic need of victims and survivors of disaster.

To supply these products and services, many actors work together and manage many logistics function (transportation, inventory management, etc.) to transform many different kinds of material and manpower at the same time. Actually, we mentioned that about 80% of the response activities are logistics (Tomasini & Wassenhove, 2009). The reason we do not put too much importance on the individual logistics functions does not mean they are beyond our scope. But in a supply chain approach, the reality that each function affects the others directs us to look at the big picture. We view the response phase as a bunch of products and services supplied by a company. But in contrast to the commercial sector, in this response phase there is just a company and a customer. There is no competition or different products that customers can choose from. So deciding a customer level and measuring it seems impossible today; but may be possible in the future as the data and awareness increases, at which point we will see more predetermined levels of operations. So, taking the traditional commercial service level as a threshold for response activities is not appropriate. Also, each natural disaster needs a different amount of products and services. In Section 2, we defined the factors affecting the logistics network in natural disasters. Even the effects of natural disasters of the same type in different regions can be very different. This makes taking the numbers produced in the response phase by logistics functions and using them as a performance measurement difficult to interpret meaningfully.

We used the word ‘chaos’ when we mentioned the environment that the response phase operations must operate within. To manage the response effectively and evaluate the success of efforts for supplying these products, we need different performance measurements from performance metrics used by commercial supply chains. After a disaster strikes, a sudden, somewhat unexpected demand for special products occurs and

it is not possible to supply enough to meet this sudden demand in a short time. But it is essential and vital to meet this demand to save lives. Also, the infrastructure designed for and operated during our daily life suddenly becomes inadequate for transporting the goods needed by victims. Many actors who do not know each other start to work together to supply many unknowns.

As we tackle these difficulties, our effectiveness will increase. Therefore, we propose three main metrics as our performance calculator. These metrics are: time frame reached to the equilibrium of demand and supply, transportation utilization, and connectivity (level of information sharing). Each of these is explored in the following sections.

1. Demand and Supply Equilibrium

A market is a group of buyers and sellers of a particular good or service. The buyers as a group determine the demand for the product, and the sellers as a group determine the supply of the product. In a market, demand and supply interact according to price and quantity and reach an equilibrium. At equilibrium, the price and the quantity of the good that the buyers are willing and able to buy exactly balances the price and the quantity that sellers are willing and able to sell (Mankiw, 2007). We can assume that the equlibrium point is the optium that satisfies, on average, both sellers and buyers.

As we see, when we mention a demand for any good or services we should also take into account supply and equlibiruim for a more through analysis of overall satisfaction. In the response phase of any disaster operations, the objective is saving lives and satisfying the basic needs of victims.

When a disaster hits, our daily routines change suddenly, and the first reaction this change will engender is an effort to turn back to our normal lives. For this to happen, if we were trapped, first we need somebody to save us. If we are injured, we need health assistance. In this situation, we can take victims as buyers, disaster management as seller and the activites we defined earlier as products and services. So, we can discuss demand and supply patterns for the products and services in the natural disaster response phase.

Disaster not only changes our daily routines, but also damages the transportation and information infrastructure. We showed the importance of these two infrastructures in Chapter II, Section 2 for a supplier to mobilize its products in an effective way.

When we take the command and control center in disaster management as final seller and the relief organizations as suppliers, the seller has no ability to immediately supply as much as demanded because many times disasters strike suddenly and the forecasting period or planning period is very short; demand usually outreaches the capacity of local governments and local businesses immediately following the disaster. But the victims (buyers) need the products and services as early as possible because unless they get those product and services, their lives will be at stake.

The most important difference between a normal market and the disaster response is that the immediate demand is beyond supply capabilites. In a natural disaster, demand is determined according to logistics factors we defined in Section 2. If we are able to forecast those factors accurately, they will give us a demand function for products and services. The second important difference is that both the buyer and seller have no concern over the price, but rather the urgency. The time is critical for both sides to achieve their common goals. So we can take the quantity and time as the determinant of the demand and supply equilibrium in the disaster response phase. As time passes after the disaster hits, at equilibrium the quantity of goods that the sellers are able to supply will balance the quantity that buyers need.

In Figure 5, we see the demand and supply patterns in a disaster. At the beginning a sudden demand arises for relief products and services but there is no or little supply for these products. (Maybe police and firefighters can supply these products for small emergencies.) After that, demand increases because as we get data from the affected area and population, our predictions change accordingly. Supply continues to increase but because of insufficient resources, infrastructure and assessment errors, which are also inefficient information sharing indicators, it is not possible to match the demand immediately. After a while we learn that the numbers that came to the command and control center after the first assessment were wrong and the new data says there is less demand at this time. In this way, after a while, demand and supply converge. But,

because of assessment problems, we may eventually encounter more supply than demand. And when we get close to the recovery period, both supply and demand stabilize and reach equilibrium again.

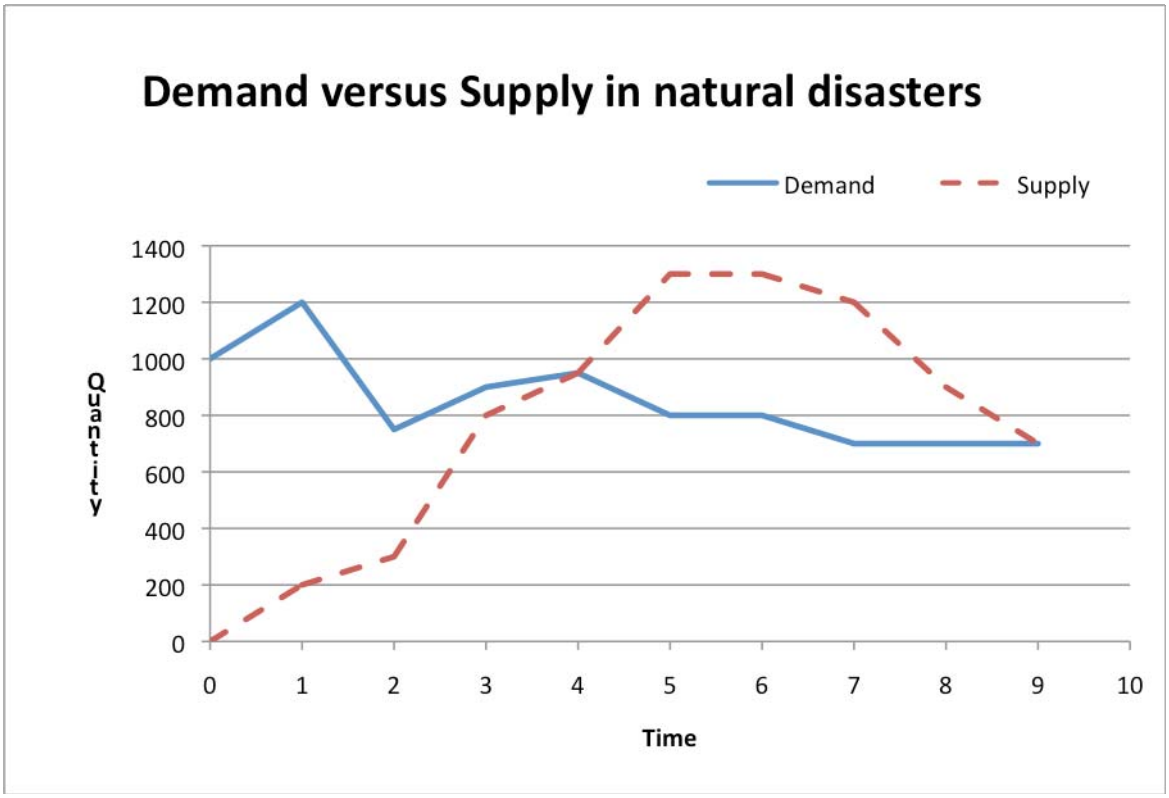

Figure 5. Demand and Supply Equilibrium in Natural Disasters

Time is critical in the response phase as indicated by the law of 3s mentioned earlier. When we encounter an emergency, if we do not have enough SAR teams, the victims trapped in the building will die soon. If we do not provide enough health service, and feed the people, the risk of a communicable disease will increase and also the resulting security and health problems will make the impact of the disaster worse. These realities make the urgency of supply critical and on the other hand, although we have enough resources outside the disaster area, it is not possible to mobilize them in a short time. But we know that an effective logistics network enables faster reaction to the needs of victims. Better use of the damaged transportation resources and sharing the information across the responders will determine the time when equilibrium is reached.

In traditional management policy, managers look at the operations or activities individually, and do not employ systems thinking. For example, you can use your damaged transportation network to mobilize only SAR teams and equipments and you can have a high SAR success, but if you do not have enough health providers for the victims whom the SAR teams rescued from the disaster area, then the response operation cannot be deemed a success.

We know that delivering the products and services we defined in previous sections needs an effective supply chain and evaluating the success of this chain by looking at individual products it delivered is not a thorough analysis. However, by looking into the demand and supply equilibrium for individual products, we can get important information about the performance of logistics networks and see the bottlenecks that will affect the performance of this type of logistics network. This will help improve preparedness and effective logistics operations in future natural disasters.

In the immediate response phase, of all products and services the most critical ones are food and water. There are a couple of reasons for this. First of all, these are bulk items and will occupy much of the damaged transportation resources. Secondly, they are needed to prevent a secondary disaster such as a pandemic and are vital ingredients for basic daily survival.

Another issue we should address here is the inability to have enough information to accurately chart demand and supply functions. The nature of the response phase makes it impossible to have accurate data about demand and supply. In the chaotic environment of this time frame, responders concentrate on helping the victims as much as possible and they put less importance on gathering data, and in many cases lack an information system needed to record the numbers. To tackle this problem, looking at equilibrium of demand and supply, we can look at the unmet demand numbers; this will reduce our data needs and give the same information. Figure 6 shows the demand, supply and their difference as unmet or surplus. The reason for surplus may be an inaccurate assessment or an excess of donations. The surplus may be harmful for overall operations because it uses limited capital and infrastructure, but its effect is not as high as unmet demand because the priority in the response phase is saving lives and decreasing the impact of the disaster on

victims. The main characteristic for food and water demand is its certainty. As long as the number of victims does not change, the need for these items will not change much, because the minimum and maximum level of need was limited by our nature.

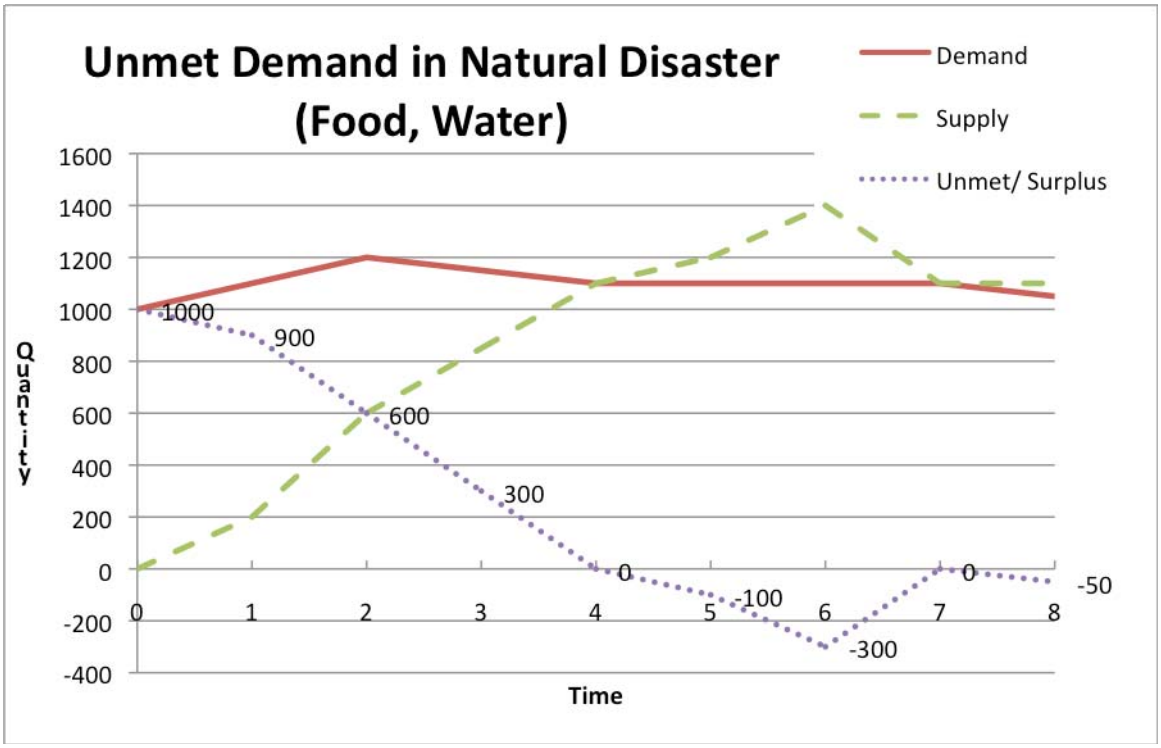

Figure 6. Unmet Demand in Natural Disasters (Food, Water)

As seen in Figure 6, the supply is increasing every day, probably because the transportation utilization and information sharing are increasing and the chaotic environment is becoming less chaotic each day. In the first two days, the food and water probably will be supplied by local capacity. But, as the natural disaster is often beyond the limits of local capacity, reaching the equilibrium in the first days is not possible. One important characteristic of unmet demand is that its value decreases as time passes. However, the same amount of unmet demand has a higher value at day one than at day two because of the vital role of the goods demanded on victims. There are not any defined values for these products for each day but we can use the law of 3s to assign these values. For example, water's value after day three should be zero if victims couldn't have any water , because nobody can survive more than 3 days without water (there are occasional, exceptional examples in disasters). Also, we cannot compare two different

disasters just according to the time when there is no unmet demand, because the quantity of the unmet demand would be different in each disaster. Because of these differences, evaluating the performance according to area under the unmet demand curve will give more accurate information than just the time when the unmet demand became zero.

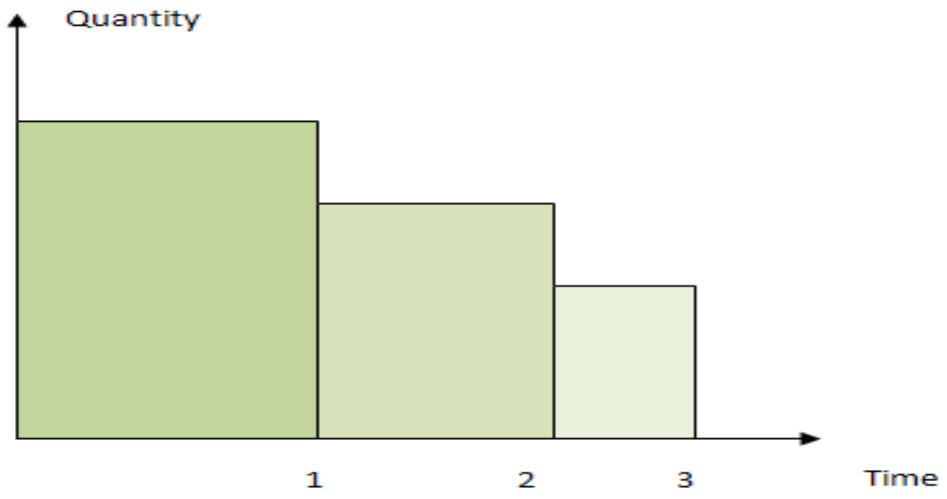

Figure 7. The Value of Unmet Demand in Response Phase For Each Day

The problem for this analysis is that any researcher will not find enough data for a through analysis. As mentioned earlier, recording the data is not a primary concern in current disaster management. Because of this problem, although the method we mentioned is above more accurate, the most accessible way of evaluating the demand and supply equilibrium may be the day on which it is reported or annotated that there is no problem with food and water supply. The assumption behind this reasoning is if the relief items started to reach to affected areas from outside, it means that the pipeline was initiated and the biggest hurdle for transferring these items was partly solved. So, we will get the day on which all demand for food and water is satisfied as our demand and supply equilibrium performance indicator, which we use in the next chapter.

2. Interrelationship Between Transportation and Logistics Networks

Transportation plays an active role in supporting and assisting logistics networks by providing an efficient and effective flow of supplies. It directly affects the result of the

logistics activities during the immediate response phase of natural disasters. According to the WHO practical guide for "environmental health in emergencies and disaster," the following are some of the basic transportation activities seen in the response phase:

- moving assessment and operational teams
- moving people affected by disaster
- moving equipment and supplies
- trucking water
- moving human bodies
- moving solid waste

The key elements in a transportation system are drivers, vehicles, paths, and fuel. These four elements determine the ability to move supplies. The first 24-72 hours of the response phase are the most vital time period for emergency assessment, search and rescue, and other emergency relief activities. If we can make a good estimation of what and how much we will need to move, we can plan a good system for transportation.

There are several prerequisites for an effective transportation system to deliver the appropriate supplies in the appropriate amount in optimal condition, where and when they are needed. There are different factors that affect the four key components of the transportation systems. We should bear in mind that a chain is only as strong as its weakest link. If one of the components does not have the required amount or desired condition, even though we have enough for the other components, it does not mean anything from a logistics point of view. The more and faster we obtain the necessary components, the more efficient logistics we can perform. The following are the factors that should be considered in order to establish an effective transportation system.

- Type and number of vehicles required: The variety of the vehicles required may include heavy construction vehicles, ambulances, buses, fuel and water tankers, etc. The amount and type of vehicles differ according to the type of the natural disaster. Even though buses can be the most necessary vehicle for evacuation operations during hurricane disaster, graders and heavy construction vehicles can be the most vital ones following an earthquake.

- Type and number of drivers required: One of the other important decisions is about the number and characteristics of the drivers needed. Because of the huge variety of the vehicles, it is important to plan where we will deploy required drivers in advance. Generally, there had been shortcomings in the number of bus and ambulance drivers in the response phase (Wolshon, 2009).
- Path conditions and operating constraints: Road closures, repair of damaged roads, and the reopening of roads are the most common scenarios after a disaster. The faster roadways can be reopened, the sooner available capacity can be reached to support the response activities.
- Fuel source availability and refueling stations: Typically, vehicles can run out of fuel in this phase. Because of that we should consider the procedures to deliver fuel, refueling stations and required amount of fuel need.

Figure 8 illustrates the transportation capability in the first seven days of the response phase according to the capacities of the three key components. In this figure, the x-axis denotes the days in the response phase (i.e., zero in the time axis shows the sudden happening of the natural disasters), and the y-axis denotes the amount of available resources of the four important components. We assumed that in day zero, we do not have any resources on hand and at the end of the seven days, we will reach a capacity of 100 vehicles, drivers, paths, and fuel.

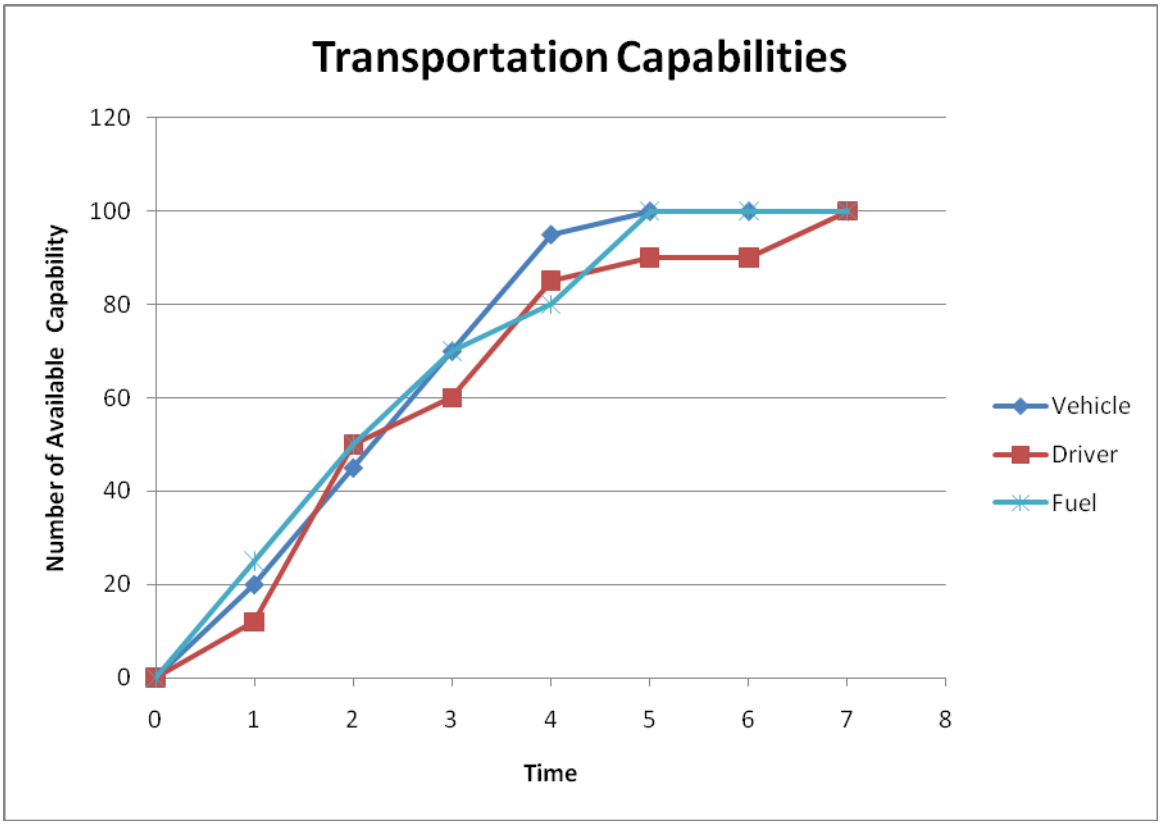

Figure 8. Transportation Capabilities during Natural Disaster

This figure indicates the impact of the three key components on the transportation capability. For instance: in day two, we can only use 45 vehicles even though we have 50 available drivers, and fuel available for 50 vehicles. In day 4, we have 95 vehicles, 85 drivers; we can only use 80 of them. The reason for these situations is the limited availability of fuels.

After we analyzed the importance of these key components, we figured out that even though we have enough capacity of vehicle and driver, and fuel, we cannot reach the intended level of the transportation system, due to operating constraints of the path.

Because of this inference, we designated available path conditions as a separate transportation metric for analyzing the effectiveness of the system. Figure 9 explains the percentage of available road structures from day zero to the 7^{th} day of the response phase.

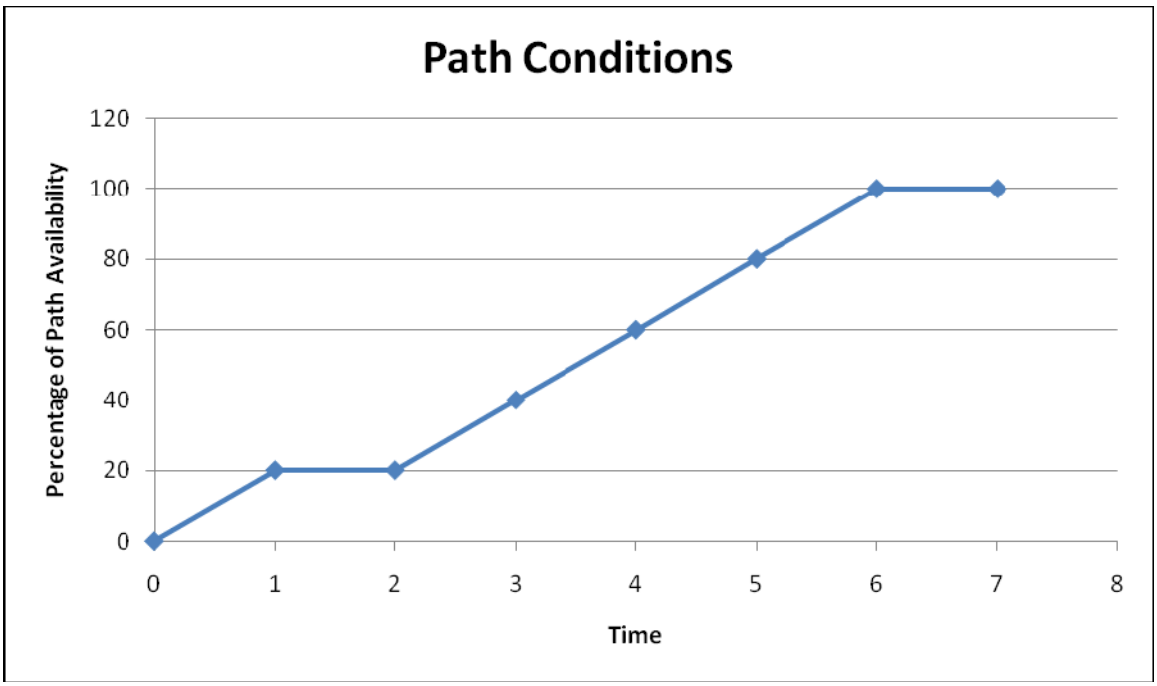

Figure 9. Impacts of Path Conditions

According to our metrics, we will look for the data about the percentage of available roads to analyze the effectiveness of the transportation system. The faster the responders reopen roads, the sooner they will get a more effective logistics networks during the immediate response phase.

3. Connectivity (Information Sharing)

As mentioned in Chapter II, information constitutes the virtual layer on which a logistics network depends.

> Logisticians in general need information that is not tough to get. Most places we go, there are ongoing operations so we can recycle information and update it. If you are in the field and have questions you are going to answer them by interacting with colleagues and partners. In most cases a website is hard to access and decisions need to be made quickly with local and current knowledge.
>
> Douglas Osmond, former officer of the United Nations Joint Logistic Command (Tomasini & Wassenhove, 2009)

A supply chain is founded on critical flows of material, finance, people, knowledge and information. For a humanitarian supply chain, information flows are the glue holding the components of the network together. During the response phase, the main problem of the actors is to acquire timely and accurate information from different categories; thus, an information management system must be set to gather raw data, to process it into relevant information, to distribute this information and then to get feedback. There are three categories of information; the first category is related to the field assessment process. It is basically the translation of the level of damage of the affected area and population into demand in term of required resources. The second category is the information related to supply in term of available resources during the response phase and what will be available in upcoming phases of the disaster relief operation. The third category is the feedback of the different actors to update and recycle the information that will be provided.

Collaboration and coordination between the actors operating in the same scene of disaster management is more than necessary; it is an obligation. Although some human operators are attempting to move as “free lancers,” their actions would be more beneficial if they were harmonized within a centralized organization. Furthermore, due to this lack of coordination many bottlenecks would appear during simultaneous operations in the same affected area.

A logistics information system has a noticeable effect on enhancing the logistics activities and provides continuous support across the different phases of the disaster management cycle including immediate response, “Humanitarian logistics information system can eliminate the duplicated data and offer more timely and accurate information during the response phase. This doesn’t just increase the efficiency and effectiveness of the disaster response, but also assists in later phases of the disaster management cycle”. (Howden, May 2009).

Establishing a logistics information system has two major requirements. The first requirement is to have the data treatment function centralized within the operation command center, because the raw data collected from the different agents need to be transformed into relevant, valuable, accessible information. In fact, during the response

phase, processing data cannot be the task of the elements deployed into the terrain because of the overwhelming tasks they have to execute. At the same time, these elements need information to conduct their operations and can provide raw data about the situation in the field and feedback about their activities. The second requirement is to create better opportunities for collaboration between the operating actors. Collaboration and coordination are strongly based on sharing information.

Information sharing is one of the major factors affecting the logistics network supporting a disaster relief operation. During operations, humanitarian actors are greatly challenged when it comes to information sharing. Many issues affect the level of information sharing and reduce, as a result, the potential effort deployed for the response operation in term of logistics activities. For a better understanding of the problem we will expose the major issues.

Weak information management: “Despite the growing recognition of the importance of information and knowledge management, this activity is generally handled poorly across the humanitarian relief sector and, to a great extent, the sector reinvents itself with each new catastrophe” (Maiers, Reynolds, & Haselkorn, 2005). The need of capturing and applying past experiences cannot be fulfilled without a good information management system able to store and manage information and knowledge. In fact, lessons learned from previous disasters will not be useful if they are not published and made available for improving future operations.

A decentralized design will affect the ability of harmonizing activities and set barriers amongst the actors. Lack of communication, due to the decentralized organizational network structure, will not help in providing the required global view of the situation and will affect the quality of the information needed for the different response activities.

The design of the logistics information system within the central command: Procedures and rules of communication have to be adequately set and properly adopted and respected by the elements deployed in the theater of operations. The design of the system must be understood by the whole organization; otherwise, many conflicts will appear and affect the ongoing operation.

Information and communication technologies infrastructure: To be performing well, an information system must be supported by an efficient IT infrastructure (hardware and software). The lack of these technologies will affect the ability to communicate data and information soon enough and will deteriorate the level of communication. In order to use the information sharing level as a metric, we suggest evaluating it according to two parameters:

- Relief network design: A binary parameter stating two options: the first option is that the network design is centralized, which means that there are different actors working under the same command or at least organizing their operations within a single operation center; the second option is that the network is decentralized, which means that responders are independently operating without a centralized operations command.
- Existence of a logistics information system: A binary parameter saying whether a logistics information system was established between field actors or not. A logistics information system is identified according to two parameters. The first is the virtual sense, where the existence of a logistics information system means that a consensus related to the exchange and the sharing of information was established between the different actors participating in the relief operation. This consensus is introduced by a set of protocols and procedures organizing the exchange of data and information. The second parameter identifying the logistics information system is the existence of an efficient Information Technology infrastructure supporting the flows of data and information exchanged between actors. This parameter evaluates the physical logistics information system.

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IV. ANALYSIS OF THE THREE DIFFERENT NATURAL DISASTERS ACCORDING TO THE ESTABLISHED METHODOLOGY

In this chapter, we will identify the current state of disaster relief operations and the effectiveness of humanitarian logistic networks, including delivery of supplies, transportation, evacuation, and sheltering by governments and private organizations. In order to analyze the effectiveness of their logistics networks, we have chosen the following three natural disasters:

- Hurricane Katrina, 2005
- Asian Tsunami, 2004
- Haiti Earthquake, 2010

We have chosen these natural disasters in order to examine a variety of logistics networks responding to different types of natural disasters. They also are fairly recent and catastrophic disasters. In the analysis of each natural disaster, we will first present background information that explains generally what happened and when during these disasters. Secondly we will analyze the logistics networks according to our metrics that are defined in Chapter III. Finally, we will summarize each disaster according to its effectiveness level.

A. HURRICANE KATRINA

Hurricane Katrina was a devastating hurricane that hit Florida and the Gulf Coast between August 23 and 31, 2005. Katrina first hit Florida August 25 as a Category 1 storm, strengthened to a Category 5 from a Category 3 in just 12 hours over the Gulf of Mexico, then hit the Gulf coast August 29 as a weaker but dangerous Category 3 (Knabb, Rhome, & Brown, 2006). The damage stretched across 90,000 square miles—an area roughly the size of Great Britain—and at least 1,330 people lost their lives. Thousands of Gulf Coast residents lost their livelihoods, and many were forced to permanently relocate (Chappell, Boening, Swanson, & Forgette, 2007).

Katrina was arguably the greatest natural disaster in modern U.S. history. Although it was not a category 5 hurricane, the economic losses, estimated at $96 billion, made Katrina the costliest hurricane in the history of the United States. The following figure shows the magnitude of Hurricane Katrina compared to Hurricane Andrew. According to this figure, 300,000 dwellings were destroyed and 770,000 people displaced after Katrina's landfall.

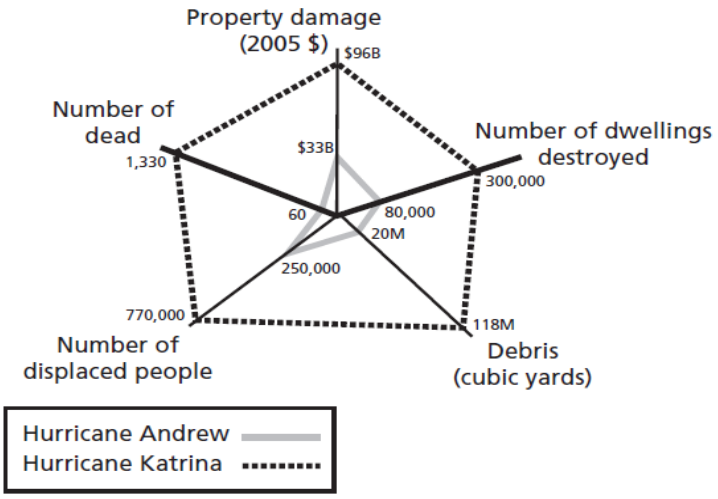

Figure 10. Characteristics of Hurricane Andrew and Hurricane Katrina (From: The White House, The Federal Response to Hurricane Katrina, 2006)

Hurricane Katrina was a very large-scale natural disaster for which federal, state, and local governments were not prepared. Relief efforts could not get to the required level in the very short run after Katrina's landfall. The speed of rescue and relief operations was the most important issue discussed after the disaster. As a result, in the Gulf Coast region, millions of lives were impacted because of the lack of available transportation, shelter, food, water, drugs, etc. (Iqbal, Mehler, & Yildirim, 2007).

The response to Hurricane Katrina involved an inter-governmental (federal, state, and local) and cross-sector (public, private and non-profit) network of actors. National Guard and active duty military troops deployed in record numbers to support the Hurricane Katrina response, including assisting with search and rescue efforts, commodity distribution, communications, evacuations, security, and medical care in the affected areas. However, the Department of Defense approval process at times delayed

the arrival of assistance and coordination with FEMA seemed to be lacking in some instances (DHS Office of Inspector General, 2006). According to the Fritz report (Fritz Institute, 2006), Figure 11 depicts that a huge number of organizations participated in the response activities, from fire and rescue services to army, and from church groups to local police.

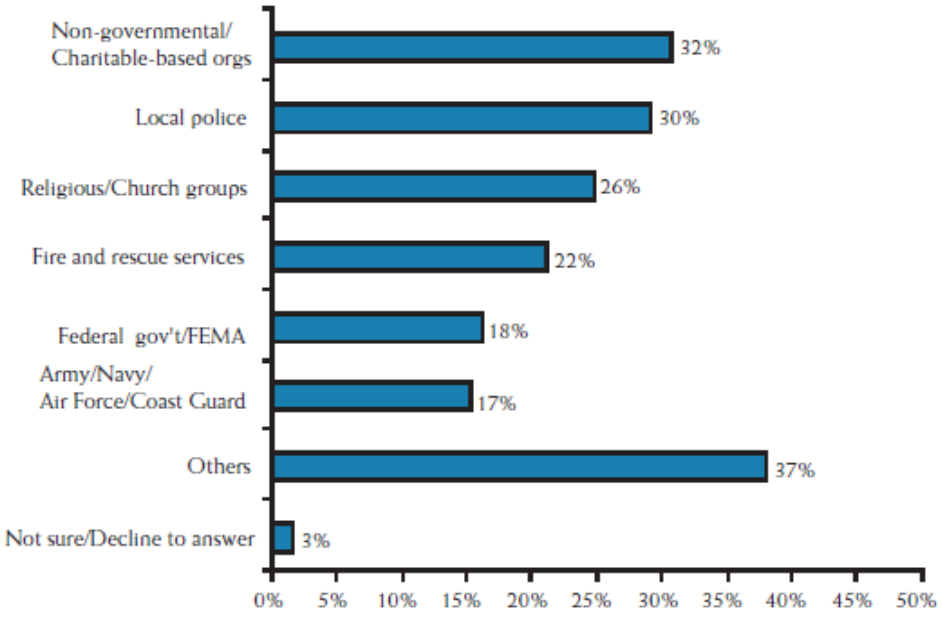

Figure 11. In the First 48 Hours, Who Came to Help? (From: Fritz Institute/Harris Interactive, 2006)

In the aftermath of Hurricane Katrina, the state of emergency management has been questioned in the U.S. Much of the frustration deals with the manner in which local, state, and federal agencies interact in the framework of the NRP. Much of the criticism appears to revolve around federal agencies' inability to be immediately available to coordinate the emergency response activities (Kapucu, 2006).

Katrina's Gulf Coast response phase lasted twelve days, during which victims were evacuated, rescued, fed, sheltered, and given medical care. The response phase began at 9:00 a.m. on August 26, when the White House declared an impending disaster and deployed federal resources. The federal emergency response began three full days before the hurricane landed. The response phase ended on the night of September 6, when

only ten thousand people remained in New Orleans and the emphasis shifted to recovery (Carafano & Weitz, 2008). We will evaluate the effectiveness of the twelve days of the response phase, which covers the logistics activities in different emergency operations according to the three metrics defined in the prior chapter.

1. Demand and Supply

In order to understand the effectiveness of the logistics network during Hurricane Katrina, we first tried to figure out the scope of the operations. The size of the disaster made even extraordinary efforts insufficient. Again and again, for evacuation, medical response, search and rescue, and temporary shelters, government efforts were unprecedented. But they were not comprehensive or rapid enough given the scope of the crisis (Moynihan, 2009).

Second, we looked for information related to demand and supply equilibrium for supplies such as water and food. The important data for us was to determine the date when the unmet quantity of food and water is zero. According to our searches, we found the following information from different sources.

FEMA used historical data and planning assumptions to gauge whether an adequate supply of commodities were on-hand. However, in Hurricane Katrina, some of the parishes had surplus commodities, while others lacked the commodities due to miscalculating the needs for the evacuees. According to FEMA logistics officials, this was because of the excessive or uncontrolled orders. Ironically, some FEMA and state field personnel suggested they had to order twice as much to get half of what they needed primarily because they had no confidence in a system that had no asset visibility. One JFO published a commodity status report as of September 5, 2005, which indicated that between August 27, 2005, and September 5, 2005, they had received less than half of what they requested for ice, water, and meals ready to eat (MREs) at all three of their commodity staging areas (DHS Office of Inspector General, 2006).

The hurricane left the citizens who remained in New Orleans in dire condition. Some were injured, and others were distressed with a lack of food, water, or medical care. The local and state governments that requested supplies such as food, water, and ice

often only got a portion of what they requested from FEMA. This led to widespread shortfalls of supplies. Moreover, it appeared that FEMA did not even have a good tracking system of the available supplies and where they needed to go (Pinelis, 2006).

Major deficiencies in commodities pre-staging could be observed during Katrina. Only 30 trucks of water, 15 of MREs, 2 of tarps and 30 of ice water were at the FEMA base. FEMA's FCO of Mississippi, William Carwile wrote, "System appears broken…will now attempt to get product in alternate ways." Carwile further criticized that commodities were delivered inefficiently and ineffectively to Mississippi and Louisiana (Iqbal, Mehler, & Yildirim, 2007).

In total, FEMA undertook a logistics response that moved 11,000 trucks of water, ice and meals into the region after Katrina, more than three times as many truckloads as were used during all of the hurricanes that occurred in 2004 (Moynihan, 2009). Despite this otherwise impressive supply, the huge amount of demand made the Hurricane Katrina response ultimately unsuccessful. As the days dragged on, it became increasingly apparent that almost every aspect of the response was falling far short of what was needed (Howitt & Leonard, 2009).

We did not find enough data to evaluate the effectiveness of the logistics network on the metric of supply/demand equilibrium. Another problem is that even those numbers that were recorded are not the same. They change from one organization to another. For example, according to the United States Army Corps of Engineers (USACE), there were approximately 5,000 truckloads of both ice and water that were brought into the region (Bourget, 2005). However, FEMA reported that 11,000 trucks of water, ice and meals moved into the region after Katrina. This issue of conflicting numbers continues to be a hindrance to evaluating the effectiveness of the logistics networks. Because of this uncertainty, we cannot identify exactly when supply met demand. The JFO report does tell us, however, that through September 5th (9 days after the hurricane) all the needed supplies had still not been delivered.

2. Interrelationship Between Transportation and Logistics Networks

According to our metric, the percentage of available path condition has a huge impact on the effectiveness of transportation networks, as much as the other components of the transportation. Even though we have enough capacity of vehicle, driver, and fuel, we cannot reach the intended level of the transportation system, due to operating constraints of the path.

Because of that, we looked for the data that express the available capacity of roadways day by day, and explain when we reached full capability to use the roadways in transportation. In our research, not only did we look for the data about the availability of the roadway, but we also looked at the other three components of the transportation in order to better analyze the effectiveness. The following are the different types of information about transportation operations performed during the response phase of Hurricane Katrina.

Major routes through Alabama, Florida, Louisiana, Mississippi and Texas were closed, with the most severely damaged being the 100-mile route between New Orleans and Pascagoula, Mississippi. In New Orleans, the Pontchartrain Expressway (the downtown section of I-10) was under water and the Twin Span, a portion of I-10 on the east side of New Orleans, was completely destroyed, causing a break in I-10. Beyond roads and highways, the rail system was severely damaged. Five major ports in the Mississippi River basin—with an annual volume of more than 450 million tons of cargo, more than 6.5 times the volume of Long Beach and three times the ports of New York and New Jersey—halted operations (Devlin, 2005).

Along the coastal area where storm surge was severe, many roads were heavily damaged and/or had significant deposits of debris, further hindering traffic and recovery efforts for several weeks. Throughout the Gulf coast, bridges sustained minor to major damage, with several in Mississippi and Louisiana completely collapsing. Similarly, countless railways and roads were impeded by massive piles of debris (DesRoches, 2006).

The scope of the disaster dramatically reduced the capacity to use transportation to deliver food, water and medical supplies, allow responders to reach affected areas, or evacuate people. In New Orleans, for example, city buses were flooded, even though they were staged in areas that had not seen flooding during previous storms. In any case, most potential drivers had already evacuated (Moynihan, 2009). Poor transportation planning could be seen during Hurricane Katrina. FEMA Director Brown accepted that FEMA had been experiencing difficulty in moving commodities during Katrina. FEMA was short of drivers to deliver commodities. FEMA officials started reviewing resumes on Saturday, August 27 to hire additional truck drivers. Almost 70 more truck drivers were needed to move commodities (Iqbal, Mehler, & Yildirim, 2007).

As a result, we found information about path conditions immediately following the Hurricane Katrina. But we didn't reach any specific data about the full availability of the roadways day by day. Anyway, we figured out that there was a difficulty getting to destinations in the response phase that affected the logistics networks. Inefficiencies of loading and unloading affected the speed of the transportation. The other factors that affected transportation badly were the inadequate number of drivers and vehicles. Because of the lack of drivers and vehicles, lots of people waited in vain to be picked up and taken to shelter.

3. Information Sharing

We searched for data to use in our two metrics related to connectivity. Relief network design and existence of logistics information systems are the two important factors that affect the success of a logistics network. We will list and evaluate the following information according to our metrics.

The Katrina disaster cannot be classified as a surprise. In both the short and long run, ample warning of the coming disaster was met with insufficient preparation. Communication was a very big problem, especially given the level of destruction in the infrastructure. Hurricane Katrina also proved that effective communication and collaboration between different agencies is needed to facilitate timely disaster relief (Iqbal, Mehler, & Yildirim, 2007).

The Command and Control Plan outlines the chains of command, identifies who the specific commanders are, as well as their backups, how they can or cannot transfer that command, and what are the specific roles and responsibilities; it should state that higher level executives should not be able to usurp authority from designated commanders. During Hurricane Katrina, the breakdown was between local, state, and federal commanders who did not want to relinquish control; the transfer of control is defined in the laws governing emergency situations in the state and federal arenas and was not properly executed during the event. Government agencies at all levels need to take a hard look at their emergency response procedures. Exactly who was in charge and who was responsible for making the tough decisions seemed unclear in the days prior to and immediately following the storm (Striedl, Crosson, & Farr, 2006).

The size of the disaster also eliminated much of the communications systems, limiting the ability of responders to gain situational awareness, or to communicate operational plans. Over three million telephone landlines were lost in the affected states, including many 911 call centers. Wireless phones were also affected, with approximately 2,000 cell sites out of service, and few places to charge the phones because of widespread power loss. The physical locations of Emergency Operation Centers were rendered unusable due to flooding or other damage, eliminating a base for command operations and resulting in poor coordination and wasted time as responders looked for new locations (Moynihan, 2009).

Hurricane Katrina caused significant damage and outages in the telecommunications infrastructure. This impeded reporting and coordination, and significantly affected the efficiency and effectiveness of disaster response efforts. However, FEMA plays a key role in communications by providing interim communications support to emergency managers and responders when the infrastructure cannot support the needs for operational capability and when field sites are established. FEMA needs to strengthen its capabilities to provide communications support during the initial disaster response when the infrastructure is most weakened and emergency responder teams are still establishing operations (DHS Office of Inspector General, 2006).

Our metrics related to information sharing did not provide us a beneficial measure to evaluate the effectiveness of Hurricane Katrina's logistics networks. Although there is a network design in response activities, there is not an information system due to the catastrophic impact of Katrina. Because of that we did not decide whether the Katrina logistics network was effective or not. The destruction caused by Hurricane Katrina increased dramatically due to communication failures. The communication failures caused undue death and destruction in the affected areas. The first responders were unable to coordinate search and rescue operations efficiently and effectively without communications to guide them to the locations requesting assistance. Supplies and assistance from other states could not be delivered in a timely manner due to lack of communications. Lack of interoperability of communications equipment presented another problem (Meeds, 2006).

4. Conclusion

Although much has been written about Katrina, it is hard to find reliable data separating fact from fiction. The sources vary greatly in quality and objectivity. Most press and online "blog" accounts are of little use. Books rushed to print are anecdotal and consist mostly of complaints. Conclusions of official investigation are fairly reliable but reflect a defensive attitude–many lessons learned reports dwell on details and emphasize faults (Carafano & Weitz, 2008).

As a result, we did not reach enough data in order to evaluate the effectiveness of the logistics networks. This is due to the lack of reliable data that was recorded during the response and especially the immediate response. Generally, responders give more importance to helping the victims, and providing supplies, than recording how much food or water they provided.

A principal reason for the inadequate response was the enormous regional destruction of communication and transportation infrastructure caused by Katrina. The areas affected by the hurricane experienced shortages of essential services, including electricity, potable water, food, and fuel (Bourget, 2005).

B. 2004 ASIAN TSUNAMI

Measuring 9 on the Richter scale, the earthquake that hit under the sea near the northern Indonesian island of Sumatra on December 26, 2010 was the strongest earthquake in the world had seen for 40 years. The massive 1,000 km rupture along the Australian and Eurasian tectonic plates resulted in huge tsunami waves (or sea surges) crashing into coastal areas across South and East Asia, even reaching Eastern Africa. (Shah, 2005). Entire coastal zones were destroyed, with the tsunamis causing damage up to 3 km inland in some cases. It killed over 227, 000 people in 14 countries located in the region and caused U.S. $10 billion's worth of damage. It displaced more than 1.7 million people. The countries with the most deaths and largest losses of livelihood were Indonesia, Sri Lanka, and India (Thomas & Ramalingam, 2005). Because some of the countries affected by the tsunami were tourist destinations, many people from over 40 countries lost their lives in this catastrophe (UNICEF, 2006). Table 2 below shows the affect of the disaster in each country.

Table 2. Impact of the Indian Ocean Tsunami Disaster (From: UNICEF, 2006)

	Dead or Missing	**Displaced**	**Losses (U.S. $bn)**
India	16,389	647,599	1.22
Indonesia	166,334	566,898	4.45
Malaysia	74	8,000	-
Maldives	108	21,663	0.6
Myanmar	59	-	-
Sri Lanka	35,262	519,063	1.45
Somalia	150	5,000	-
Thailand	8,240	-	2.2
TOTALS:	*226,616*	*1,768,223*	*9.92*

The disaster was especially notable because of its impact on the affected people and nations; it was way beyond the capability of the many countries most affected to

handle the relief effort without outside help. Apart from the magnitude, the public attention around the world made this disaster unique and special. It triggered an unprecedented global public response in the form of donations (Scheper, Parakrama, & Patel, 2006). People and countries made donations of more than U.S. $14 billion and the United Nations initiated its biggest relief operation in its history. This high level of attention and generous help were a cooperative effort of media and relief organizations. After this disaster, the disaster management and relief efforts gained more public attention and created a new consciousness in the business sector and academic environment about disaster management.

The local authorities or governments in countries were the first to help to victims. In some countries, the government was slow to respond and international, regional and local NGOs were given relatively free access to tsunami-affected areas. In some countries, the government (central, state and district levels), local NGOs, international NGOs already operating within the country, private sector and religious groups all set the relief process in motion (Thomas & Ramalingam, Lessons from the tsunami: Top line findings, 2005) . India and Thailand turned down outside help and national resources provided almost the whole response. (Cosgrave, 2007).

1. Demand and Supply

There were many problems in the Asian Tsunami that we can see also in other disasters affecting the demand and supply equilibrium and its continuity. First of all, correct assessment is crucial for any agencies to supply needs in a timely manner. A correct and timely assessment makes the logistics operations more effective and so helps save lives or prevent misuse of the inadequate resources that can be used in other emergencies. In the Asian tsunami, assessments were of variable quality and assessment reports failed to influence relief action. Aid providers, who were from different countries, presumed the needs of affected populations and hence the supplies were sent based on limited information. In some cases, it was observed that some organizations were not aware at the time that the actual number of people to care for was drastically lower than anticipated because of the great loss of life from tsunami waves (Perry, 2007).

Another problem that may affect the assessment was that the area hit by the tsunami was geographically dispersed and evaluating the situation in such wide area requires highly developed technology together with historical data and logistics expertise. Both lack of experienced logisticians and lack of sufficient high-technological assessment measurements might have hindered the assessment problems in this disaster.

As in many disasters, the local capacity was not enough to respond to the disaster in a timely manner. One of the examples is lack of enough health care capacity. Lee, Low, Ng, and Teo (2005) stated that there was a shortage of health care facilities, staff and supplies. Of about 130 doctors and nurses working at the hospital prior to the tsunami, only 30 were available post-disaster.

For the agencies that have enough capacity, there were other problems that hindered the lead times in their logistics networks. For example, UNICEF, which is one of the biggest and most experienced humanitarian organizations, felt the enormous impact of the tsunami in its logistics network UNICEF's supply division found itself shipping goods to eight different countries, negotiating fast-changing customs regimes, having to coordinate with a plethora of other relief actors, working through and supporting joint mechanisms, such as the Joint Logistics Centre of the UN (UNJLC), and in the case of Banda Aceh, having to liaise with military authorities for access and warehousing (UNICEF, 2006).

Lack of experienced personnel caused other problems, like forecasting errors or insufficient logistic analysis. For example, none of the agencies foresaw the outbreak of tetanus and anticipated the high incidence (Lee, Low, Ng, & Teo, 2005). Another example of insufficient logistics analysis is a supply problem UNCEF experienced in the Maldives. Perhaps a third of the 4,000 rainwater harvesting tanks distributed by UNICEF in the Maldives were not installed during the critical rainy season because UNICEF had not tied down the details with its partners of who would provide parts and do the installations work (UNICEF, 2006).

The donations were generous but because of management problems sometimes the wrong materials were delivered to victims. One of the findings of the Fritz Survey

indicates that, in addition to the ineffectiveness created by logistics mistakes, in Sri Lanka provision of used clothes that were climatically or culturally inappropriate proved to be humiliating (Thomas & Ramalingam, 2005).

The disaster was unpredictable and the countries that were hit were not ready for it. But this was not the only problem to supply the demand effectively. Another characteristic of the demand was its rate of change. Figure 12 below shows the oscillation of demand and the capacities of organizations in Aceh, Indonesia.

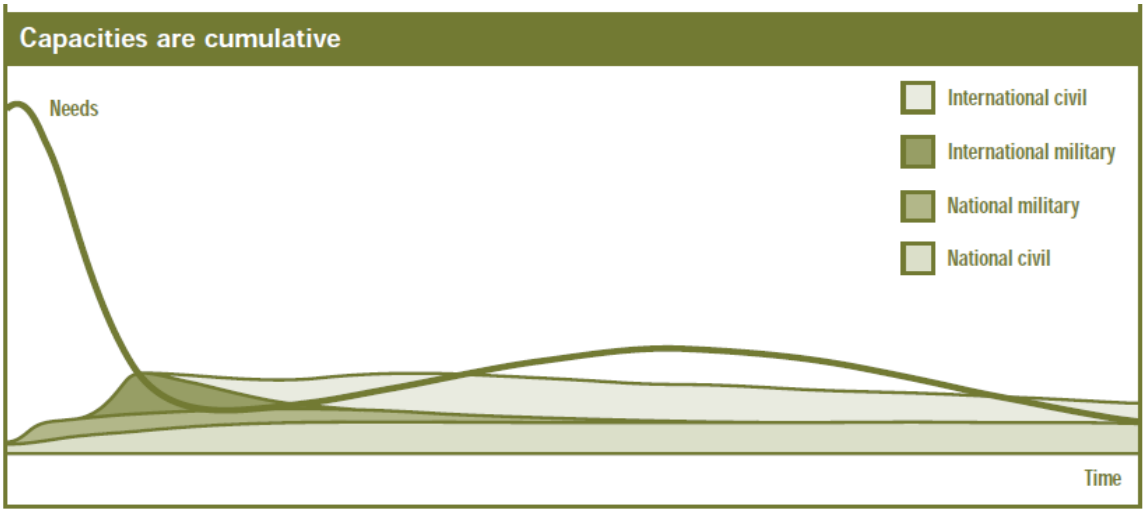

Figure 12. Mixture of capacities in the response in Aceh (From: Cosgrave, 2007)

In this demand pattern, there is a crucial choice managers had to make. You can select the affected group for limited resources or you can deliver the limited resources the entire affected group. But with more efficient relief operations you can improve both the number of beneficiaries served and the quality of service.

While the number of agencies sometimes resulted in better levels of service for the beneficiaries, it is also led to duplication and waste. For example, there were so many field hospitals for so few patients that the medical staff from two different hospitals scuffled over a patient. Prosthetic limbs continued to flood into Aceh even after the number of limbs donated exceeded the numbers who need them (Cosgrave, 2007).

Although there were many problems, the relief effort was seen as generally successful in stemming the ongoing widespread deaths due to hunger and disease that can

occur in the aftermath of a natural disaster. However, as was widely publicized in the media, the relief effort was organizationally and logistically hindered, particularly in the early post-tsunami days (Perry, 2007). Although there is no clear information about on which day the responders satisfied food and water needs of victims, there are numerous report and news about the relief problems. Some agencies declared in their reports that they started to supply basic needs on day two (International Organization For Migration, 2005) and according to the IFRC report (2005) in Indonesia on average, 1.5 million liters of clean drinking water were produced daily during the emergency phase. But, news reports published on December 31, 2004 said that there was still a food crisis in the disaster area. One report (Middleton & Macdonald, 2004) stated, World Health Organization crisis team leader David Nabarro said as many as five million tsunami survivors were not able to access what they needed to live. Either they cannot get water, or their sanitation is inadequate, or they cannot get food," he said." Another newspaper (MacCharles, 2004) reported, "the escalating world-wide effort to help the countries devastated by the tsunami will likely be inadequate, U.N. Secretary-General Kofi Annan admitted yesterday." But, after December 31, we don't see any news about the food and water crisis. The only clear information is that, three months after the disaster, WFP declared the hunger crisis averted (WFP, 2005).

2. Interrelationship Between Transportation and Logistics Networks

It was the local people who undertook the rescue and relief work and who saved lives in the first day or so prior to the arrival of international agencies (Perry, 2007). Because the relief work was local, in the first day the inbound transportation was not a concern of relief work in the areas where local relief capacity was available.

But the disaster damaged buildings and roads, and subsequent tsunamis destroyed almost all the structures along the coast. The airport and land routes to the major towns had been severely damaged (Lee, Low, Ng, & Teo, 2005). In Indonesia, tsunamis destroyed government offices and transport infrastructure. The tsunamis destroyed main roads that ran near the coast and bridges along the coast of Sri Lanka and Aceh. The main

airport at Aceh was unusable for a while because of flooding. Aceh's main seaports were also destroyed. The lack of access meant that it was up to 10 days before the most isolated groups got outside help (Cosgrave, 2007).

The relief items such as bottled water are bulk material, which takes more room to deliver. The relief agencies used their own ways to deliver the needs in their capacity. The insufficient transportation sometimes made this effort impossible or relatively late. According to a post-tsunami report (Scheper, Parakrama, & Patel, 2006), one INGO had planned to hire a fleet of civilian helicopters but found that there were simply not enough available on the market for the short-term contracts at short notice.

Transportation infrastructure in the disaster area was devastated and this was the biggest strain in delivering the relief items to the victims. There are several reports saying that some stockpiles remained in airports on December 31, 2004 because of lack of road availability to get through the items. But after the Indonesian government let foreign military forces operate in the disaster area, those forces started to use their transportation vehicles and this enabled more usage of available paths to deliver the goods even to sea-locked areas. This increased utilization began after the foreign military operations started in the middle of January. For example, according to NBC News (Windrem, 2004), the U.S. intelligence community tasked its spy satellites to check on the transportation infrastructure to see what can and cannot be used to bring supplies to the tragedy's victims.

Although after a while the transportation performance increased, according to the Fritz report (Thomas & Ramalingam, 2005), in both India and Sri Lanka aid agencies reported low capacity for warehousing and transportation. Figures 13 and 14 show the results from a survey that was conducted March-April 2005 and asked the availability of relief resources to the NGO workers who worked for helping Asian Tsunami victims in India and Sri Lanka.

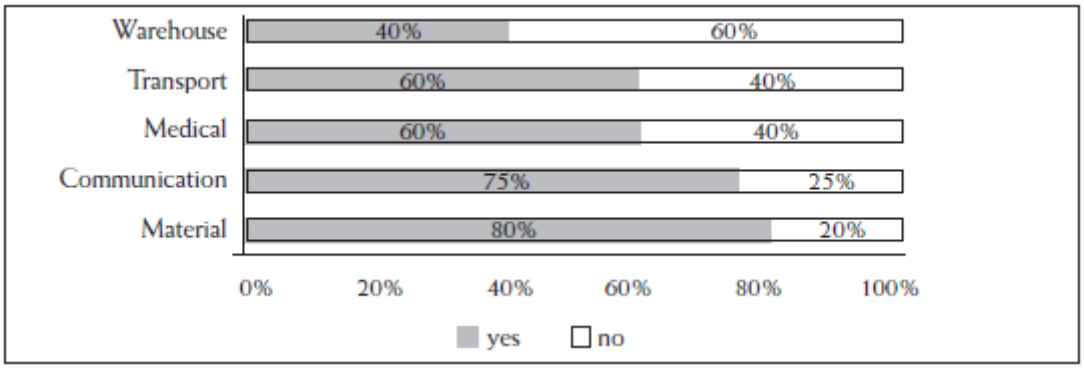

Figure 13. NGO Responses About Resources Available for Relief-India (From: Thomas & Ramalingam, Lessons from the tsunami: Top line findings, 2005)

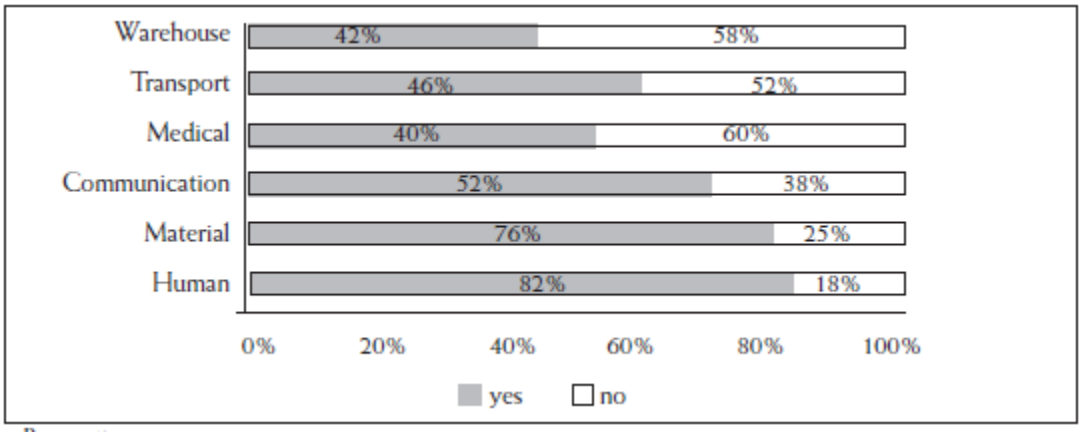

Figure 14. NGO Responses About Resources Available for Relief-Sri Lanka (From: Thomas & Ramalingam, Lessons from the tsunami: Top line findings, 2005)

The insufficient transportation and warehousing capacity, together with the flood of unsolicited supplies such as used clothing, forced immediate distribution (Thomas & Ramalingam, 2005) and created a chaotic environment at the hubs. This immediate and unplanned distribution made the supply organization and relief efforts more vulnerable to any change in the demand.

Despite cautions that aid agencies put out against sending unsolicited items, they were confronted with stream of gifts sent by well-meaning donors. Sri Lanka's airport reported that within two weeks of the tsunami, 288 cargo flights had arrived without airway bills to drop off humanitarian cargo (Thomas & Fritz, 2006). Another striking

example of the chaos in airports was an anecdote by a health worker in Aceh, Indonesia. She portrayed the scene she saw when she got the airport as chaos: "We arrived in Banda Aceh on the evening of the 28th December on a charter plane carrying 3.5 tons of relief goods and eight staff. The airport was in chaos. Hundreds of people had gathered there, desperate to get on the next flight out and plane after plane was trying to land…That night we slept in the airport while two of our team went to check out the city centre. It was difficult to get there - the entire transport system was down - but somehow they managed. When they returned, they warned us that the streets were full of the corpses of humans and animals."

3. Information Sharing

The disaster was one of the biggest response activities the world has ever seen. There were many organizations in the disaster with different skills, cultural norms and business practices. Within several weeks of the disaster, approximately 400 international non-government organizations were working in Indonesia alone, providing basic assistance to the affected population (Perry, 2007).

The coordination was multi-dimensional and included governments, local NGOs, international NGOs, national and international military, local people and participants of logistics networks of each NGO. Coordination sometimes happened at high levels, and sometimes it was very poor within the different organizations. The coordination between national military and international military was well coordinated but there was poor coordination between international civil capacities and national and international military capacities (Cosgrave, 2007).

The number of relief organizations and the political problems, together with different cultural norms, made the coordination more difficult and complex due to lack of enough leadership. To solve this problem, the United Nations appointed a publicly well-known figure, ex-U.S. President Bill Clinton, to coordinate the efforts.

It is logical to expect all organizations to work together with the same objective, saving lives. That is a natural instinct that in emergency, people hold each other tightly. But this is not always case in disaster management, as this disaster illustrated.

Sometimes, the participating agencies have their own operating methods and sometimes there is competition amongst them for limited resources (Perry, 2007). According to the International Federation of Red Cross and Red Crescent Societies, some of the agencies guarded information to ensure their 'niche' (Walter, 2005). Increased competition between agencies for beneficiaries led to agencies' moving into sectors outside their competence and reduced information sharing between agencies (Cosgrave, 2007).

There were also some local constraints. Parts of Sri Lanka had both government and Tamil Tiger administrations. In Indonesia, continuing administrative reform left some local officials in doubt over which level of government was responsible for what (Cosgrave, 2007).

The tsunami affected many countries, some of which opened their doors wide to foreign NGOs and militaries, and some of who provided only limited access to disaster areas. But in both cases, a centralized command was used in one form or another. In the first, the disaster effort was managed by the biggest international organizations and local government; in the second operation centers were established.

According to the Fritz report (Thomas & Ramalingam, Lessons from the tsunami: Top line findings, 2005), the respondents in India and Sri Lanka observed that NGOs collaborated well with each other. In India, 70% of the participating agencies indicated that they had collaborated in some way with another agency, and in Sri Lanka this number was much higher at 85%. Although some IT companies helped governments to establish information systems (IBM, 2005), we can't say whether these were information networks to share information across the responders.

4. Conclusion

The relief phase was effective in ensuring that the immediate survival needs were met through a mixture of local and international assistance in the immediate aftermath of the disaster. However, these relief responses were generally not based on joint needs

assessments and were not well coordinated, leading to an excess of some interventions, such as medical teams, alongside shortages in less accessible areas or less popular sectors, such as water supply (UNICEF, 2006).

There was no communicable disease during the tsunami disaster. This is an important achievement in such a disaster to prevent communicable diseases. The reason for this success is twofold, partly the experience of health organizations and partly the high coordination and role of national and international military (Cosgrave, 2007).

According to the Fritz survey (Thomas & Ramalingam, 2005), the aid provided during the first 48 hours was mostly from private individuals or the local community. But in most of the countries, the service provided by international NGOs was more appreciated than government services. This may be explained by the experience and skills some NGOs have in this type of operations.

Also, there are lessons about the effect different cultural norms may play in such operations. For example, people in India also expressed humiliation at having to receive charity, especially in the form of used clothes, which did not always meet the local cultural norms (Thomas & Ramalingam, 2005).

Unlike other disasters, there were no funding gaps this time (Cosgrave, 2007). This does not necessarily means there was not any lead time factored into logistics operations. Even though organizations had enough monetary resources, they still had to make contract, buy and deliver the goods that were not available in warehouses. But, having enough donations made a good example for showing that even with unlimited resources, effectiveness is a management skill achieved by high-level expertise.

During the tsunami, the rush to help in any way possible resulted in mountains of used clothing and inadequate medical help. Also, where central points of communication and disaster protocols had been established in the community, the loss of life was significantly less (Thomas & Ramalingam, 2005). It is a great lesson for any person who wants to help people in need. Sending unnecessary items to the people in disasters sometimes affects the relief operations badly. If agencies and governments use their

networks effectively, they can prevent the problem at the origin before it comes to the disaster area. Of course, this only can be achieved with a well-educated needs assessment made by professionals.

Also, there were very good examples of the involvement of local business (a part or representative of international corporations). Citigroup provided office space in Bangkok for UN operations coordination. DANONE, the French food corporation, donated millions of packages of high-protein biscuits, water, and milk drinks through its network of local distributors, as well as through the UN's World Food Program and Red Cross (Thomas & Fritz, 2006).

Also, as a conclusion, we can say that the water and food need was satisfied in a timely manner. After a while, the responders began to use the damaged infrastructure more effectively. The information sharing naturally was not so high but the media coverage forced every responder to work more carefully. When we consider the magnitude of this disaster, we can say that the relief effort was generally successful according to our metrics.

C. 2010 HAITI EARTHQUAKE

At 4.53 p.m. on January 12, 2010, an earthquake struck the city of Port au Prince, capital of the Caribbean Republic of Haiti, and the nearby cities. The magnitude was measured at 7 on the Richter scale and the center of the earthquake was located 16 miles away from the capital. The environment in which the disaster happened contributed largely to the enormous level of damage that affected the population and the infrastructure. In addition to the strong power of the earthquake and the 59 aftershocks varying from small shakes to quakes measuring almost 4 on the Richter scale, there were others factors that made the damage so huge. The first factor is that the majority of the affected area is urban with a great concentration of population. The main affected cities were Port Au Prince (population almost 2,000,000 people), Carrefour (approximately 334,000), Leogane (about 134,000), and Gressier (about 25,000). The second factor is that the percentage of urban population living in slums was about 86% (Rencoret, Stoddard, Haver, Taylor, & Harverey, 2010).

> It is estimated that 3 million people, approximately a third of the overall population, have been affected by the earthquake. The government of Haiti is reporting an estimating 112,000 deaths and 194,000 injured. Reportedly, 700,000 people have been displaced in the Port Au Prince area and many without shelter, with an estimated 482,000 people who have left for rural areas, with the possibility that this number will reach a million. (Margesson & Taft-Morales, 2010)

The United Nations Office for the Coordination of Humanitarian Affairs (OCHA, 2010) mentioned average levels of infrastructure damage equaling 40% to 50% in the majority of the affected area and reaching 90% in some locations.

With almost the total destruction of the government and public facilities and the United Nations Mission facilities, the Haitian Government experienced a near collapse and a chaotic situation. The government could not carry out a significant relief operation and asked immediately for international help.

Although international aid started flowing on the second day from the neighboring countries such as Dominican Republic, Cuba, Peru and the U.S., many issues interrupted and delayed the rescue teams and the flow of necessary items. Within the first 72 hours, there was no possibility to establish a global field assessment to conduct a fully organized operation from the beginning.

We can divide the response phase into two periods; the first was the immediate and the second was the sustained response phase. The response started immediately after the disaster January 12, and did not cover all the affected areas until January 15. By the $16^{th,}$ the picture was clearer with the increasing flow of information, international rescue teams, aids and medical supplies. On January 23, the Haitian government declared the end of rescue efforts, which meant the end of the response and the starting point of the recovery. In the following sections, we will evaluate the logistics network supporting the response phase according to the three metrics established in Chapter III. As mentioned in the former chapter, this analysis will include demand and supply equilibrium of food and water, path conditions or the interrelationship between transportation and logistics network connectivity and information sharing levels.

1. Demand Versus Supply Equilibrium Studying The Duality of Demand Versus Supply in the Case of the 2010 Haitian Earthquake During the Response Phase Is Challenging Because of Two Factors

- The inability of the local authorities and the different aid organizations deployed in the area to provide a definitive rapid assessment of the situation. This is due to the fact that they were subject to important damage in personnel, equipment and infrastructure. This damage reduced their capacities to provide a global rapid assessment.
- The impossibility of conducting a global definitive assessment determining the adequate level of demand in a short period, due to the high level of damage.

In the Haiti case, the field assessment was made in many steps as the timeline of the response was advancing. The first elements to start this assessment were the local authorities and the United Nations humanitarian community in Haiti. At the same time, other assessments were made:

> Early in the response, the first damage assessments were conducted remotely based on satellite imagery obtained from the United Nations Institute for Training and Research Operational Satellite Application Program, the European Union's Joint Research Center (EU/JRC) and Google Earth, providing an overview of the extent of damage and population displacement and informing preparation of the general flash appeal. Following the arrival of the UNDAC team to Port-Au-Prince a number of ground and aerial assessment conducted to verify information from the remote damage assessment and identify needs of affected communities. (Rencoret, Stoddard, Haver, Taylor, & Harverey, 2010).

> …within 24 hours of the earthquake, the United State began deploying search and rescue teams along with support staff. (Margesson & Taft-Morales, 2010)

The goals of these assessments are to set the list of response activities and then identify the required items that need to be provided.

> In the first two weeks following the earthquake, priorities were focused on 1) search and rescue assistance, including teams with heavy-lift equipment, medical assistance and supplies 2) addressing a critical need

> for food, clean water and sanitation, medical assistance and emergency shelter 3) setting up key infrastructure and logistics operations. (Margesson & Taft-Morales, 2010)

Identifying demand for food and water in terms of quantity was difficult during the early stages, but the quantity of supplies was increasing along the response timeline.

> WFP and its partners are conducting an operation to provide two-week rations to 2 million people in Port-Au-Prince through a new fixed distribution site system. OCHA reports that the government of Haiti is also providing food kits to 100,000 to 150,000 people per day…The U.N. logistics cluster is working with MINUS, SOUTHCOM and Canadian military to distribute daily rations outside Port-Au-Prince. (Margesson &Taft-Morales, 2010).

> As of the first of February 2010 U.S. military forces had delivered 2.1 million bottled waters, 1.79 million food rations, more than 100,000 lbs of medical supplies and more than 844,000 gallons of bulk fuel...Additional tasks undertaken by U.S. DoD personnel include casualty treatment, both ashore and float, and aerial reconnaissance to assist rescue/supply efforts. (Margesson & Taft-Morales, 2010)

As can be seen, an enormous quantity of food and water was sent during the response phase from the outside of the affected area; was it able to reach the affected population and to meet quantitatively and qualitatively the surge of demand? The logistics network was not able to bring up the level of supply to adjust with the surging demand during the early stage of the response phase and many bottlenecks reduced its distribution capabilities. So many questions should be raised about the factors contributing to this weakness.

The first factor was the bottlenecks that appeared all along the distribution network, due to the congestion problems in the ports, airports and the remaining logistics hubs after the disaster. The temporary capacity of these hubs was not sufficient to manage and store the increasing flow of aid that had to be offloaded.

This high flow of goods that overwhelmed the pipeline brings us to the second factor, which is prioritizing the supplies. In fact and because of the dynamic change of

the situation, setting priorities among the different kinds of supplies was a necessity during the early response phase when the distribution and the storage capacity were limited.

> A Red Cross report released in the late March observed that the ports, warehousing and trucking systems are being stressed by all the humanitarian aid coming into the country, which volumes of goods being so large they cannot be used for months; meanwhile, critical goods have no space to be imported. (Rencoret, Stoddard, Haver, Taylor, & Harverey, 2010)

Food and water are the most critical supplies that must be delivered to the affected population during the early stages of response. The local capabilities did not evolve during the response phase to compensate for the lack of external supply. In fact, the public network of distribution of drinking water, though completely undamaged was not able to provide partially the needs of the affected population. Much more, the movement of the affected population to safe locations created an unpredictable density of demand in these areas that also perturbed the bottled water distribution. The deployed distribution efforts were not able all along the time scope of the response phase to push supplies in food and water during 11 days of the response phase and the unmet demand of food and water did not decrease significantly.

In conclusion and during the response phase, the supply of food and water could not adjust to the surge in demand until the significant improvement of the network storage and distribution capabilities of food and water that occurred in the early recovery phase. Reaching the required levels and providing the required quantities for the affected population is a goal partially reached during response phase.

2. Interrelationship Between Transportation and Logistics Networks "Path Availability"

Already poor, the transportation infrastructure in Haiti was affected after the earthquake. Before assessing the interrelationship between transportation and logistics networks during the response to the Haiti 2010 earthquake, it is useful to expose the situation of the transportation infrastructure right after the disaster struck.

- Land transportation: the road network was severely damaged and the already fragile system had collapsed, making difficult the movement of vehicles through streets clogged with debris and rubble.
- Airports: among the 17 airports existing in Haiti, only three had paved runways. Affected by its limited capacity, the serious damage of its infrastructure and the destruction of its control tower, the main airport in Port-au-Prince was not able to support the arrival of large, almost simultaneous flights.
- Seaports: the facilities of the main port had been too damaged, the docks were almost destroyed which dramatically decreased the capacity of off-loading ships.

The task of transportation is to enable moving the population affected by the disaster, moving equipments and supplies, trucking water, moving corpses to burial locations, and moving debris.

In the case of Haiti, the component of land transportation was only part of the transportation system that operated to support the relief operation. In fact and due to the geographic nature of Haiti, an island, the major task of land transportation was to support distribution for “the last mile” and to sustain the ongoing operation. Air and maritime transportation were necessary for bringing external aid and equipment before being distributed and used.

The path condition during the early stage of response was deeply affected in the affected area. Right after the disaster 40% to 50% of the roads and streets in the affected areas were impassable; this percentage reached 90% in slums. In addition to the deep damage of the road network in the affected area, the identification of available paths was impossible at the first stage of response until the intervention of the U.S. military and many private companies. At the early response, path conditions diminished strongly the capabilities of the distribution and evacuation network. Providing satellite photos and updated maps in addition to the ongoing efforts of clearing roads ameliorated the capacity of the transportation component.

Clearing roads and streets of debris required a lot of special resources including vehicles like bulldozers, trained drivers and fuel. The contribution of local population in providing manpower to this ongoing effort helped to clear some critical paths inside the capital Port-Au-Prince.

Although partially executed during the response phase, moving debris from the road network contributed to improve the distribution activity of aid and the sanitary evacuation of injured and dead victims to hospitals and morgues.

3. Information Sharing

> A range of humanitarian information management tools and mechanisms were used throughout the earthquake response. The inter-cluster web site 'one response' was piloted in Haiti and served as online platform for the humanitarian community to share operational data and information related to response and recovery. Clusters' information management representatives met on a regular basis to agree on common data standards, exchange information and develop indicators to track the effectiveness of their work. (Rencoret, Stoddard, Haver, Taylor, & Harverey, 2010).

During the early stages of the response the situation was chaotic; the remaining communication infrastructure was unable to support the flow of communication. Government officials were virtually unable to communicate with each other; aid workers had to rely on delivering messages using ground transportation or on expensive and hard-to-access satellite phones.

The situation changed by the arrival of UN Disaster Assessment Coordination teams and international search and rescue teams. These teams were using the Virtual On-Site Operation Coordination Center for mobilizing and coordinating their deployments.

A report published by the U.S. Department of State (Humanitarian Information Unit) mentioned that,

> The January 12 Haiti earthquake ushered in a new information environment: one with unprecedented availability of raw data in all forms, the growing usage of new information communication technologies and the emergence of three loosely connected humanitarian communities of interest. These three communities of interest were centered on the US Government; the United Nation and International community and a new

> group (Information and Communication Technologies) volunteers comprised of virtually-connected academics, humanitarians, corporate foundations and ICT professionals. (HIU, 2010)

Following the first chaotic stage of response, the level of sharing information improved by the arrival of outsider support and the engagement of many actors who coordinated their activities through the use of ICT capabilities and the setting of information clusters. The U.S. Air Force and the World Bank/Image Cat also provided customized GIS and satellite imagery analysis for conducting the humanitarian operation.

Although the logistics network operating during the response was not centralized, the establishment of the "one response" website contributed enormously to harmonize the actions of the actors operating in the field. The website centralized in a virtual sense the network and permitted creation of a meaningfully coordinated operation.

A logistics information system also existed because of the creation of this website; the periodic meetings were the occasions to develop the necessary protocols for the information system. In the material dimension, the external aid provided a wide range of equipment to build an infrastructure capable of supporting the virtual dimension of a logistics information system.

Globally, the level of information sharing improved significantly after a stage of "incomplete situational awareness" by the intensive use of ICT and the implementation of information systems. Despite this great contribution, there were two major problems. The first is that the huge volume of data can affect the quality of information and mislead certain actions. The second is that improvising an information system for every disaster is not the ultimate solution. It would be better if these information systems were integrated into a global decision process system already available for use by the different actors.

4. Conclusion

The Haiti earthquake was one of the world largest catastrophes. The size of damage, combined with the already poor condition of the infrastructure, were the origins

of the problems that affected the capabilities of the logistics network at the first stage of the response phase. The evaluation of the logistics network according to the designated metrics brought the following conclusions:

- The equilibrium between demand and supply of food and water during the response phase was not reached due to the large size of casualties and affected population. The unmet demand of these two items did not drop to zero until the recovery phase.
- The path condition limited the movement of rescue teams and vehicles inside the affected area. As a result, the distribution capabilities were reduced to a low level until an advanced stage of the response.
- The information sharing level was good because of the existence of an information system with its two components, the virtual “protocols” and the material “infrastructure.”

Meanwhile, the performance evolved during the following stages of the crisis due to many factors:

- A good level of information sharing that enabled the humanitarian actors to coordinate and collaborate and find solutions to the bottlenecks faced in the terrain.
- The increasing amount of supply provided by the different donors to meet demand.
- The support of the U.S. military in the different phases of the response.

The logistics network that operated during the response saw a huge improvement from a low level of capacity to a significant level in the final stage of response, which greatly enhanced the effectiveness to meet the field requirement at the beginning of recovery.

V. MANAGERIAL IMPLICATIONS AND RECOMMENDATIONS

In this chapter, we will explain the managerial implications of the three different natural disaster response operations (Hurricane Katrina, Asian Tsunami, and Haiti Earthquake), and especially logistics activities during the immediate response phase. According to these implications we will express our recommendations to help establish better logistics networks. Each natural disaster has its own unique characteristics. For instance, the most important activity in Hurricane Katrina was emergency evacuation, as opposed to search and rescue in the Haiti Earthquake. Particularly, we will specify all problem areas according to our three measurements related to effectiveness of the logistics operations and then list our solutions to improve logistics planning.

A. DEMAND AND SUPPLY

A successful disaster relief logistics effort can only be performed if we have the right amount of material in the right place at the right time. This is the basic reality of response phase that must be stressed. Although in all of the natural disasters first 72 hours is the most critical time zone, generally the amount of supply cannot meet equilibrium with the amount of demand in this period. According to our metrics, when supply reaches the amount of demand earlier, the logistics network performs better. For instance, one of the most tragic aspects of the Haiti Earthquake was the complete absence of emergency responders in the initial hours and days following the earthquake. On January 14, there were no search and rescue teams, police presence, caution tape, cleanup crews, heavy equipment, food or aid stations, or any assistance of any kind. While this situation changed in the following days as international aid poured in, the lack of immediate assistance may have cost many their lives (Fierro & Perry, 2010). Because of that a formal distribution system was not established in the immediate response phase that would meet the response needs.

The problems are based on the ineffective planning processes of responders in all levels, from local to government and from private to non-governmental organizations. With the help of good planning and pre-positioning of supplies and equipment, we can

prevent delays and shortages. According to the Fritz report about perceptions of the affected in Hurricane Katrina, while local organizations, government agencies and national non-profit organizations provided relief post-Katrina, there were significant differences in the amount of time that passed between the hurricane and the arrival of relief across the region. As was reported in the media, it took significantly more time to get to some groups of people (Fritz Institute, 2006). Figure 15 illustrates the response time during Hurricane Katrina. According to this figure, while 41% of the victims received help, almost 21% of them did not receive any help even in first seven days.

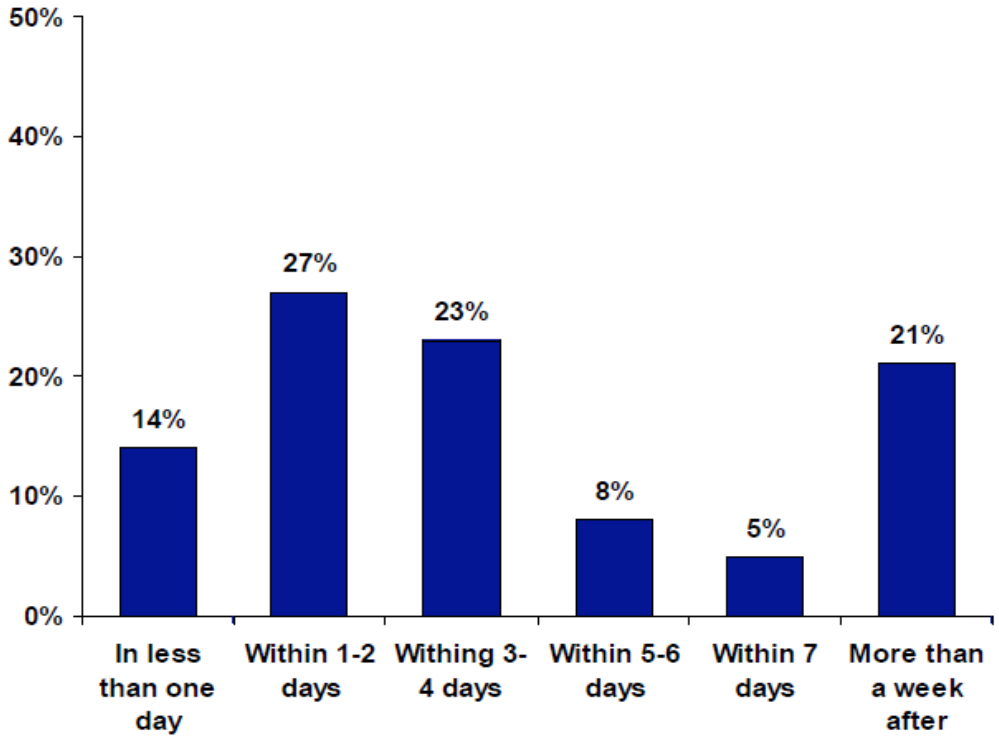

Figure 15. Date of First Help Reached from Outside Victims House Following Hurricane Katrina (From: Fritz Institute/Harris Interactive, 2006)

Pre-positioning of certain types of resources will be required immediately before and after a disaster; this is a key to supplementing state and local response efforts. These resources include commodities such as food, water, ice, and baby formula; medical, veterinary, and search and rescue teams; supplies such as pharmaceuticals; and equipment such as generators. This allows responders to provide immediate assistance

while standby contracts are activated, supply chains are established, and coordination with other logistics support agencies can be completed to address specific requirements (DHS Office of Inspector General, 2006). In order to decrease response time and reach the supply and demand equilibrium earlier, another solution can be establishing distribution centers and warehouse networks closer to the affected area. With these logistics networks, we can deliver needed resources to the victims of the disaster at the right time.

Especially when responding to sudden onset disasters (natural disasters that occur without a transitional phase such as earthquakes), an established pre-positioning network would be most beneficial by eliminating the procurement phase of the response (Duran, Gutierrez, & Keskinocak, 2009). After the disaster onset, the organization will use the designed network to conduct daily operational decisions over a planning horizon that covers the disaster duration (Ichoua, 2010).

Centralization of the ordering process for supplies and equipment is another factor that can be useful to decrease the response time. During Hurricane Katrina, FEMA headquarters decided to centralize the ordering process for ice and water. Therefore, the Operations or Logistics Section of FEMA immediately forwarded action requests for these commodities to the Logistics Response Center. Unfortunately, FEMA lacks standardization in resource ordering, has an inefficient and ineffective system for tracking a request, and the same information is entered into at least three tracking systems that are not linked. FEMA needs a resource tracking system that is capable of documenting whether requested resources were delivered and the efficiency with which the resource was provided. This would allow responders to monitor both operational and contractor performance (DHS Office of Inspector General, 2006).

B. INTERRELATIONSHIP BETWEEN TRANSPORTATION AND LOGISTICS NETWORKS

Transportation plays an active role in supporting and assisting logistics networks with providing an efficient and effective flow of supplies. It directly affects the result of the logistics activities during the immediate response phase of the natural disasters. One

of the transportation system problems encountered in all three disasters is the distribution of the commodities. There are different cases in which the responders could not build an effective distribution system, though they had enough supplies and equipment to deliver.

The catastrophic nature of the disasters made it challenging for logistics networks to get supplies, equipment, and personnel where and when needed. If we do not have the ability to accommodate needed key elements in a transportation system, we cannot arrange our future operations due to lack of drivers, vehicle, path, fuel, or the payload. Road closures, repair of damaged roads, and the reopening of roads are the most seen scenarios after a disaster occurred. For instance; in the Haiti earthquake, while the airport was functioning, the port was damaged and many roads were impassable. In addition, the nearest large airport, Las Americas International Airport in Santo Domingo, was already reported to be congested. The large number of operational agencies moving in to the affected areas presented logistical and administrative challenges as well (IFRC, 2010). In order to decrease the impact of damaged infrastructure on the roadway network, we should have contingency plans for possible transportation by rail, sea or air.

Utilizing technologies such as RFID and real-time tracking systems will ensure an effective transportation system. For instance, in 2004 FEMA Logistics received approval from its headquarters to pilot an asset visibility system, which involved tracking equipment being placed on selected trucks to monitor its movement. Once surge funds became available in anticipation of Hurricane Katrina making landfall, it was estimated that 25 to 33 percent of the trucks were equipped with tracking units. However, due to software limitations of the tracking equipment, FEMA was unable to determine whether a truck had been offloaded or had changed cargo once it left its point of origin (DHS Office of Inspector General, 2006). With the help of new developments in the RFID technology, we can reach more optimal solutions in transportation. Not only we should use RFID tags for trucks that we used in the transportation, but also we should use these tags on the packages of commodities like water, food, search and rescue equipment or any other emergency material. As a result of this, we can track our supplies and find solutions to the questions such as: where is the response truck or were the needed commodities delivered to the warehouse or the distribution centers.

C. INFORMATION SHARING

One of the other criteria that we used to evaluate the effectiveness of the logistics operations is the level of information sharing. In particular, deficiencies in communication and the lack of information are the fundamental factors that affect all other operations related to the response phase. For instance, Hurricane Katrina caused significant damages and outages in the telecommunications infrastructure. This impeded reporting and coordination, and significantly affected the efficiency and effectiveness of disaster response efforts (DHS Office of Inspector General, 2006).

The effectiveness of a communication network depends as much on the participating people and organizations as it does on the communication system through which they interact (Denning, 2006). Lack of coordination of information across different level of responders is the common challenge seen in all three natural disaster relief operations. Actually, we are not surprised with the low level of information sharing. Because when we look at the operations, there are lots of different responders from military to civilian organizations, some of whom have not operated together before in any response activities. Even for some of the responders, it was the first time for them in the country in which the disaster hit.

Many times in an emergency the local responders, non-governmental organizations and governmental agencies are unable to communicate with each other. Each organization brings communications equipment to the incident, but this equipment is not always compatible with that of other organizations. For example, in Hurricane Katrina, DoD assets responded with several different devices: cell phones, blackberry(s), handheld SAT phones, handheld radios, GPS and blue force tracker. Other organizations did not necessarily have the same tools that could communicate with these devices (Meeds, 2006). In order to solve this lack of interoperability problem, there should be some communication plans that show the distribution of the necessary equipment for the affected areas and also the hierarchy between responders. By using the same type of communication devices, which use the same bandwidth or satellite connection, we can reach an uninterruptible communication.

At the same time, we can reduce the deficiencies in communication systems with the following activities:

- Plan and test mobile technologies that can be set up quickly when the regular infrastructure is down
- Arrange for security forces to protect the temporary infrastructure
- Use and test all communications equipment regularly
- Use standard software and protocols—interoperability and simplicity of interconnection will be important (Denning, 2006)

Another important factor to increase the level of communication and information sharing is to establish the communication centers as fast as we can. Centralization of the communication process can help to merge all the information in one place. With establishing communication centers, we can better analyze which region of the affected area needs more help than the other places, and so we can direct our sources to the needed victims quickly.

VI. CONCLUSIONS

A. SUMMARY AND REMARKS

In our project, we tried to find metrics to be able to assess the performance of logistics networks in disaster response operations. Unless NGOs and governments know the overall success of their activities in the response phase, the efforts for a more efficient response in future disasters cannot be successful. It is naturally hard to calculate the performance of very complex and integrated operations, either quantitatively or qualitatively. To achieve this goal, we tried to divide the logistics in the disaster response phase into manageable parts of disaster response logistics. In each chapter, after we introduced our problem statement, we analyzed these individual parts then combined them as performance metrics. In Chapter I, we introduced background for this project and our purpose. Then, we presented our research questions to clarify our purpose and defined the scope and methodology for this project.

In Chapter II, we looked into three different areas in a hope that these areas will help a better understanding of disaster response logistics. At first, because we focused on the immediate response phase, we looked to different phases of disaster operations. In this part, we introduced the reasoning behind segmenting the disaster according to different phases. There are many different phases in the literature, but we defined them as the pre-disaster, response, recovery, and reconstruction phases because they are the most generally accepted terms.

In the second section of Chapter II, we looked at the commercial supply chain concept to understand the roots of its evaluation and the components that made it so popular and successful. Supply chain management is a very broad topic. So, we just looked at the literature that we thought would identify some common concepts or ideas we could implement in disaster response operations. We analyzed the factors that create the path for this management concept. The main concepts we transferred from supply chain management to disaster management are the role of information technology and

information sharing, the idea for global optimization, the value gained by partnership and the awareness of uncertainty problem coming from both the demand and supply side.

In Chapter II, the last stop is an introduction of humanitarian logistics. We can divide the logistics into three parts according to organizational structures and objectives. The first one is commercial, second is military and third is humanitarian. These three different organizations have common logistics activities when we defined logistics as movement of goods and personnel from one point to another, but there are many different factors affecting the logistic operations because of their different strategic objectives. Because disaster management logistics is a part of humanitarian logistics, in this section we defined the principles of humanitarianism, pillars of humanitarian logistics and relation between humanitarian logistics and supply chain management. Without knowing the incentives and objectives in humanitarian logistics, deciding the priorities in disaster logistics operations will be partly wrong and incomplete. For example, commercial logistics usually deals with complex demand, but humanitarian logistics deals usually with complex emergencies and sudden supply problems.

In Chapter III, first, we decided to break down the immediate response phase as activities to analyze the logistics that will support these activities. There are many important and necessary activities but we only focused on essential managerial and logistics activities. These activities consist of establishing an operations center, emergency assessment, SAR, providing basic needs, and emergency sheltering. Exploring these activities helped us better understand logistics needs in response. The two distinctive characteristics that guided us to the role of logistics in immediate response are chaos and uncertainty.

In the second section of Chapter III, we looked at the factors that affect the dimensions of activities and tried to establish a framework that would enable the evaluation of different types and scales of natural disasters with the same logistics metrics. The size of the affected population, the size of the affected area and the level of damage are the factors that convert the activities to different but common logistics activities. Response activities and this framework helped us understand the logistics environment in immediate response. When we multiply activities by these factors, we get

a common logistics network indifferent to size and type of disaster before deciding to generalize the performance metrics for any kind of natural disasters.

After exploring activities and factors, in the third section of Chapter III, according to the expected role of logistics in the response phase, we established our logistics network performance metrics, which are demand and supply equilibrium, interrelation between transportation and logistics networks, and connectivity. At the beginning of our project, we planned to reach a comparative methodology by using quantitative metrics and wanted to validate the effectiveness of this methodology by comparing the logistics data from three different natural disasters. As we went through our research, we realized that there is not any valuable quantitative data to evaluate the performance of logistics networks in a system approach. So, we decided on three qualitative metrics that interact with each other and compromise the bottlenecks and uncertainties in logistics network in the response phase.

In Chapter IV, we explored three different types of natural disasters according to our metrics—Hurricane Katrina, Asian tsunami, and Haiti earthquake—to see whether our metrics were useable or not. The reality of each responder having different logistics infrastructure and coordination just made by assigning different actors to different geographical areas and not combining logistic networks of each responder makes creating a logistics database difficult. The most useable data were surveys made months after response operations ended. But, when we explored these three different natural disasters, the problems annotated by relief workers were found to be the same and a high level of success in our metrics means a better response in the response phase.

After we finished this chapter, we saw that the role of information sharing and partnership in commercial supply chains can be achieved by an increased level of connectivity in natural disasters. Also, together with increased connectivity, a high level of transportation utilization will also enable greater global optimization in commercial supply chains. In commercial supply chains, companies are building inventories according to their service levels to cope with the uncertainty problems mentioned in Chapter II. The level of inventory along the supply chain shows us the effectiveness of their supply chain’s performance. In disaster management, there is not yet a globally

defined service level. So deciding upon the right inventory level along the supply chain is not possible in disaster management. But, considering the agility characteristic of disaster logistics, the responsiveness of a logistics network to the demand will be an important indicator. As a performance metric, the time frame to reach demand and supply equilibrium will give us a similar performance metric in commercial supply chains. Commercial supply chains are concerned with cost, and the amount of decrease in inventory level is one of the most important performance metrics. Disaster logistics is concerned with time and we believe that speed of achieving demand and supply equilibrium is one of the most important performance metrics in disaster logistics.

In Chapter V, we explained the managerial lessons to achieve a better working logistics networks during the immediate response phase according to our metrics. Building a local capacity and prepositioning is critical for the response phase. Also, using the new technological tools like RFID will help to better coordinate distribution. Also, a centralized command and control system is critical to distribute the necessary information around the responders for a better performance.

B. FUTURE RESEARCH

One of the most striking problems we encountered while conducting our research is there is relatively little research for disaster logistics. The literature is mainly anecdotes and surveys. After the big disasters, some organizations and governments paid attention to disaster management but these efforts diminished as time passed and people started to forget the impact of the disasters. Especially, there is very little research from the top universities. It shows that there are not enough incentive and job opportunities for this field. So, as long as the issue is not attractive, research will proceed very slowly. We believe that as trade gets more and more global and urbanization gets more rapid, the effects of natural disasters on global business will be more severe. So, a research that shows the affects of natural disasters on global business like growing security issues will attract more attention both from the academic and business environment.

Another important problem we realized is lack of quantitative data about operations. Natural disasters in the same geographical area and with the same conditions

are very rare and everybody is in a rush to respond to each emergency. Gathering the relevant data for future analysis is relatively less important. The most concerned group about creating and evaluating data is health workers and we saw in our research for Chapter IV that they are the most capable organizations in such emergencies. To gather data in emergencies is as difficult as analyzing them. Technology makes important changes in every aspect of life, so we think research in this area will help in gathering more relevant and quantitative data that will enable more realistic and reliable analysis.

In emergency literature, two successive assessments are usually mentioned. The first one will be made right after the disaster; the second more detailed assessment will be made one or two weeks later. This reasoning seems very acceptable at first glance but thanks to supply chain, today we know that if the assessment at the beginning was made incorrectly and there were more than one step that turned the assessments to tangible goods or services, the mistake made at the beginning will be magnified and create a burden on logistics. So, the first assessment should be made scientifically and maybe assessment should be a new research area for creating more sound and realistic simulations.

One of the biggest bottlenecks in immediate response activities is insufficient transportation infrastructure. Even if the warehouses are full of relief materials close to the affected area, delivering these goods to victims will likely be a problem. In many cases, the disasters are beyond the local capacities and local authorities will need outside help. This means ports, if the affected area has coastline, or otherwise airports. Both may be used to transport bulk materials from the outside world to the affected area. An efficient inbound and outbound transportation will decrease the lead times and make the relief operations much faster.

We know that supply chain return would be much higher if the companies along the chain had a high level of operational efficiency. Today, many international companies implement the modern quality and management approaches to their operations and efficiency within their organizations is very high. In disaster management, before focusing on the logistics network, looking for better operations will pave the way for

better logistics network. For example, SAR operations are only analyzed within a broad emergency management. But, every emergency has unique characteristics and should have different skills and practices.

Lastly, without a baseline, it is not easy to evaluate performance of your operations. In commercial supply chains, service levels accepted by industries help build more accurate and reliable operational goals. Having the same kind of service levels in disaster management will help the responders in the same way. Some worldwide NGOs are working on some standards and they operate according to these standards. These standards may be the first milestone of generally admitted service level.

Any kind of research related with issues we mentioned above will broaden the area of new research and finally yield better disaster management. We do not know for sure whether natural disaster are inevitable or not, but we know that without an efficient logistics operation, any effort will be less valuable to victims.

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